

Towards the operational RCR system - results from pre-operational test runs

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1 Introduction

In June 2003, the Hirlam Council approved a proposal made by FMI that FMI acts as the lead centre for maintaining a regular cycle of the HIRLAM Reference system (RCR), running the Reference system operationally under close surveillance by both scientists and duty forecasters.

Preparations for the RCR system at FMI started in summer 2003. Pre-operational runs were carried out from August 2003 until January 2004. The RCR system gained the operational status on 2 February 2004.

This write-up shortly describes the pre-RCR suites and documents some validation results from pre-operational runs as well as from runs of the first operational month (February 2004). A few problems encountered during the pre-operational phase are also briefly discussed. Technical aspects of the RCR implementation are described in Kangas (2004). Information about the comprehensive tool package for monitoring and evaluating the RCR system can be found in Eerola (2004) and Kangas (2004).

2 Parallel run set-up

The pre-RCR runs, based on the HIRLAM 6.1.2 version, were run in parallel with the FMI operational HIRLAM 5.1.4 system from August 2003 until November 2003. Since December 2003 the RCR runs have been based on the HIRLAM 6.2.1 version. The runs have been conducted on the IBM at CSC (Center for Scientific Computing). In the following, short descriptions for the FMI operational suite and the pre-RCR suites are given:

FMI operational suite, ATX (Hirlam 5.1.4) :

- 0.3° horizontal resolution, 40 levels in the vertical
- 256 × 186 grid points
- Semi-lagrangian advection, time step 450 s
- 3D-Var analysis (HL5.0.3)
- 6 h data assimilation cycle
- Cut-off time for observations : 2.5 h

- Lateral boundary conditions : ECMWF 0.4° frames received 4 times a day, with 6 h temporal resolution
- Forecast length : 54 h
- Elapsed time for the forecast model : 20 min with 1-hourly output

Pre-RCR suite, NAE (Hirlam 6.1.2) :

- 0.18° horizontal resolution, 40 levels in the vertical
- 406 × 306 grid points
- Semi-lagrangian advection, time step 360 s
- 3D-Var analysis (HL6.1.2), FGAT option
- 6 h data assimilation cycle
- Cut-off time for observations : 2.5 h
- Lateral boundary conditions : ECMWF 0.4° frames received 4 times a day, with 6 h temporal resolution
- Physics changes compared to ATX : major change (6.1.1) in STRACO and soil freezing change in ISBA
- Forecast length : 54 h
- Elapsed time for the forecast model : 45 min with 6-hourly output
- Run from late July 2003 until the end of September 2003

Pre-RCR suite, V62 (Hirlam 6.1.2) :

- 0.2° horizontal resolution, 40 levels in the vertical
- 438 × 336 grid points
- Semi-lagrangian advection, time step 360 s
- 3D-Var analysis (HL6.1.2), FGAT option
- 3 h data assimilation cycle
- Cut-off time for observations : 2 h for main cycles, 4 h 20 min for intermediate cycles
- Lateral boundary conditions : ECMWF 0.2° frames received 4 times a day, with 3 h temporal resolution
- Physics changes compared to ATX : as in NAE
- Other changes compared to ATX : IDFI initialization experimentally, even though not in Reference 6.2.1

- Forecast length : 54 h for main synoptic times, else 6 h
- Elapsed time for the forecast model : 65 min with 3-hourly output
- Run from late September 2003 until the end of November 2003

Final RCR suite, V621 (Hirlam 6.2.1) :

- 0.2° horizontal resolution, 40 levels in the vertical
- 438 × 336 grid points
- Semi-lagrangian advection, time step 360 s
- 3D-Var analysis (HL6.2.1), FGAT option
- 3 h data assimilation cycle
- Cut-off time for observations : 2 h for main cycles, 4 h 20 min for intermediate cycles
- Lateral boundary conditions : ECMWF 0.2° frames received 4 times a day, with 3 h temporal resolution
- Physics changes compared to ATX : as in NAE and V62
- Other changes compared to ATX : IDFI initialization
- Forecast length : 54 h for main synoptic times, else 6 h
- Elapsed time for the forecast model : 75 min with 1-hourly output
- Run since early December 2003

The idea of the RCR runs is to stick to the HIRLAM Reference system as closely as possible. However, some modifications to the Reference HIRLAM were introduced in connection of the pre-RCR runs. The 'Finlake' option in surface analysis makes it possible to create pseudo observations for Nordic lakes from climatological data. Furthermore, additional SST and ice observations for the Baltic Sea are received from Finnish Institute of Marine Research (FIMR). These modifications were used in all pre-RCR suites as well as in the operational RCR suite.

Two other differences compared to the Reference HIRLAM in NAE and V62 suites were the parallelized surface analysis program (span.x) and the user-friendly, complete and self-explaining file names. These modifications were accepted into the Reference HIRLAM release 6.2.1 (V621).

3 Results

As mentioned in Section 2, pre-RCR systems have been run in parallel with the FMI operational HIRLAM since summer 2003. In the following, some results from these pre-operational RCR runs as well as from the RCR runs for the first operational month (February 2004) are presented. Validation of RCR suites is presented and the performance of RCR runs are compared to the FMI then operational ATX runs. Validation of NAE and V62 suites is only briefly summarized - more details can be found in Järvenoja (2004). The emphasis in validation is devoted to February 2004, the first operational month of the RCR (V621).

3.1 Summary from NAE and V62

The pre-RCR NAE system was run during August and September 2003. The NAE area was just inside the operational ATX area because the same ECMWF boundary data were used. The verification scores for NAE and the operational ATX were very similar as reported in Järvenoja (2004). One thing worth mentioning from verification may be the fact that NAE gave slightly ($0.5\text{-}1^\circ\text{C}$) lower T_{2m} values than ATX over land areas, with both (NAE and ATX) having a small negative bias.

Furthermore, a couple of other findings can be mentioned. The NAE fields (T , u , v and q) in a 0.18° resolution include clearly more noise, i.e., waves of several grid lengths, than the ATX fields in a 0.3° resolution. This problem was seen already in connection of the previous FMI operational change (2002/2003) as reported by Eerola (2003) and Järvenoja (2003). Both NAE and ATX showed positive V_{10m} bias that has been a problem in HIRLAM for a couple of years. The positive bias is more prominent in central and southern Europe and during nighttime.

The RCR system in its planned horizontal domain was implemented as the V62 suite at the end of September, and was run in October and November 2003. The V62 configuration is more complicated as it uses a 3 h data assimilation cycle. The observations are received via a different server compared to ATX, and it was found that at least aircraft reports were missing for some time. An own set ECMWF boundary frames in the actual model resolution have been received via Internet instead of the direct line (as in case of ATX and NAE). In late October, the width of the extension zone in the 3D-Var analysis was re-defined to be wide enough.

A serious problem in the V62 suite was suspected and was traced back to a smaller fraction of ice in the polar region in V62 than in ATX. The problem showed in larger bias and rms error of p_{msl} and in higher low troposphere temperatures in high latitudes in V62 compared to ATX. The problem arises from the use of the ECMWF SST field for pseudo observation creation in the HIRLAM SST analysis and consequent diagnosis of the ice cover. The wrong limit for the freezing temperature (-1.8°C instead of -1.6°C) of the sea water was used, and this resulted in too large fraction of open sea over polar regions. For this reason, the V62 runs for October and November have only limited value for model evaluation, and are therefore not presented.

3.2 Introduction of V621

Due to the problems in the V62 suite and the fact that a new HIRLAM release (version 6.2.1) became available, it was decided to introduce a new RCR suite, V621, in the beginning of December 2003. At the same time the bug in diagnosis of ice cover (a wrong freezing temperature of sea water) was corrected and the 3D-Var version was upgraded from 6.1.2 to version 6.2.1.

The V621 suite has been run since 4 December 2003. However, a new problem was detected in January 2004. The RCR monitoring tools (Eerola, 2004) were prepared at that time, and these new tools revealed that most of the Russian SYNOPs were rejected from the analysis. It turned out that the station heights in reports were zeroes ($=0$), leading to too large a difference between the observed surface pressure and that of the background field. The problem in BUFR handling software was corrected in mid-January, meaning that the V621 results for December and January are not fully representative. However, the verification scores showed that the missing Russian SYNOPs had only little impact on the forecast quality, probably due to the fact that these missing observations are located down-wind from the main verification area.

3.3 Validation of V621

Due to the problems in V621 during December and January, no verification results for these months are shown. The month of February, the first operational month of the RCR, provides the first "clean" comparison between V621 and ATX. Figures 1 and 2 show the observation verification scores (EWGLAM stations) for ATX and V621, respectively. The p_{msl} scores (top left in Figs. 1 and 2) indicate that the ATX suite has slightly larger negative bias than V621. The rms errors are similar for ATX and V621. The T_{2m} scores (top right in Figs. 1 and 2) demonstrate that V621 has a slight negative bias, whereas ATX shows a growing positive bias reaching almost 1°C at 48 h. The rms error is larger in ATX than in V621. The V_{10m} scores (bottom left in Figs. 1 and 2) show that both ATX and V621 have a considerable positive bias: ATX about 1 m/s and V621 as much as 1.5 m/s. V621 has a larger rms error as well. More information on 10-metre wind speed differences between V621 and ATX can be seen in Fig. 3, which demonstrates the geographical distribution of the systematic difference between V621 (interpolated into the ATX grid) and ATX 48 h V_{10m} forecasts, starting from 00 UTC, for February 2004. The V_{10m} values of V621 are larger than those of ATX over mountainous areas (e.g. the Alps, mountains in southern Europe and in Scandinavia) and over slopes (e.g. Greenland slopes close to coasts). The reason for larger wind speeds in V621 is most probably the smaller orographic roughness in V621 compared to ATX.

Day-to-day monitoring of ATX and V621 forecasts has revealed that the corresponding systems clearly behave in a different way. This can be seen, e.g. in daily p_{msl} maps. Small differences in the initial states between V621 and ATX can lead to considerable differences in corresponding 48 h forecasts. This is highlighted in Fig. 4, which depicts the p_{msl} difference between V621 (interpolated into the ATX grid) and ATX 48 h forecasts starting from 13 February 2004 00 UTC. Differences like those shown Fig. 4 result in large rms differences between V621 and ATX p_{msl} forecasts for the whole month of February 2004 (not shown).

Figures 5 and 6 demonstrate the p_{msl} bias in 48 h forecasts for ATX and V621, respectively. Both ATX and V621 show a considerable (more than 3 hPa) negative bias over a vast area in eastern Europe and Russia, with V621 having larger negative bias than ATX. Areas with a small positive bias can be seen in western part of the model domains in both ATX and V621. The negative bias over the continental European area has been seen in earlier operational implementations at FMI as well. However, the magnitude (3-4 hPa) of the bias in the present systems is larger than seen in recent years during the synoptically active seasons. This negative bias coincides with the area where the cyclones are already in the occluding stage. Therefore, it can be concluded that this bias might be an indication of the HIRLAM model's inability to fill the cyclones at an adequate rate, most probably due to deficiencies in physical parameterizations. The bias patterns for the 500 hPa geopotential height (not shown) much resemble those of the p_{msl} bias, suggesting an equivalent barotropic structure of the forecast error.

Figures 7 and 8 depict the geographical distribution of the p_{msl} rms error for ATX and V621, respectively. The general outlook is similar in both ATX and V621, with largest values over the North Atlantic and northern Europe. V621 has, however, larger rms errors, e.g. over the Kola Peninsula (6 hPa), over the Arctic north of Scandinavia (7 hPa) and north of the Black Sea (7 hPa). Overall, due to larger bias and rms error, the performance of V621 can be regarded as somewhat poorer than that of ATX in terms of p_{msl} .

Figures 9 and 10 show the geographical distribution of the T_{2m} bias on the station basis in 48 h forecasts valid at night (00 UTC) in February 2004 for ATX and V621, respectively. ATX

(Fig. 9) shows a negative bias in southern latitudes, while in western and central Europe the bias is small or non-existing. In northern latitudes, in Scandinavia and northern Russia, however, a considerable positive bias up to 8-9°C dominates. The bias distribution in V621 (Fig. 10) is largely similar. The values are, however, somewhat smaller than in ATX. A negative bias can be seen in central Europe as well as in northern Africa and in the Middle East. The positive bias in northern Europe and Russia is unacceptably large in both ATX and V621.

The weather conditions in northern Europe in February were very variable. There were mild periods with thaw weather but also very cold (below -30°C) periods. There were cases, when temperatures were very different in a rather small area in northern Europe. An example of this kind of case is shown in Fig. 11, demonstrating the observed T_{2m} for 9 February 00 UTC. Mild temperatures of close to 0°C are seen in the southern part of the area. Colder temperatures dominate in Finland and northern Sweden (below -30°C at some places) and -35°C temperatures were recorded over the Kola Peninsula. Figure 12, showing the T_{2m} error in the 24 h V621 forecast for this case, demonstrates the model performance in different temperature conditions. Mild temperatures in the southern part of the area are well predicted with the error being a few degrees at maximum. Positive forecast errors up to 10°C can be seen in Finland, but in Lapland and the Kola Peninsula the positive forecast error can be more than 15°C. For ATX, the error is even larger (not shown).

Forecast errors of that order motivated to further study the forecast error dependence on the observed T_{2m} . For 48 h forecasts from V621, valid at 00 UTC in January 2004 (31 cases), the T_{2m} forecast errors (forecast minus observation) were calculated on station basis for the area shown in Fig. 12 (northern Europe). Forecast errors were then classified into 1-degree categories according to the corresponding observed T_{2m} and finally the average in each class (i.e., bias) was calculated. The results are shown in Fig. 13, where the bias is plotted as a function of the observed T_{2m} . The curve with squares represent the bias distribution. The curves with circles represent bias \pm one standard deviation, respectively. Looking at the bias curve (squares), we can note that the bias is small, close to 0°C, within the observed temperature range between -10°C to +5°C. With decreasing temperature, from -10°C to colder, the bias increases rapidly, reaching +15°C at -30°C. This means that for observed temperatures of -30°C the predicted T_{2m} is only -15°C. For the observed T_{2m} of -25°C, the bias is +10°C, meaning that the predicted T_{2m} is -15°C as well. Further, for the observed T_{2m} of -20°C, the bias is +6°C, meaning that the predicted T_{2m} is -14°C. This means that the predicted T_{2m} value of -15°C can mean anything between -15°C and -30°C in reality (observed T_{2m})! This ruined the original idea of an "easy-to-use" thumb rule (bias correction) of how to correct the predicted HIRLAM 2-metre temperatures in cold cases. As a whole, the T_{2m} forecasts become less useful at temperatures of -15°C and below. The reasons for this model deficiency can be in several parts of physical parameterization, such as clouds and radiation, surface processes and turbulence. Anyway, the bias problem of this magnitude calls for urgent action.

Finally, Fig. 14 demonstrates the T_{2m} bias dependence as a function of the observed T_{2m} for analysis, 24 h and 48 h forecasts in February 2004 in northern Europe and Russia for V621. The T_{2m} analysis draws close to observations at temperatures down to -15°C with the bias being practically 0°C. Below -15°C the bias starts to grow and reaches +6°C at -30°C. In cold cases (below -15°C) the background value of T_{2m} can deviate so much from the observation that the observation is rejected in the analysis as speculated by Järvenoja (2003). This means that erroneous background field value goes into the T_{2m} analysis leading to a positive bias. The bias

curves for the predicted T_{2m} reveal that most of the bias is generated during the first 24 hours. During the next 24 hours, i.e., the difference between curves representing 48 and 24 h forecasts, the bias grows only by 1-2°C. The bias behavior in ATX analyses and forecasts (not shown) is similar except that the bias is 1-2°C larger.

4 Summary

The RCR system has been implemented at FMI and it has gone through thorough testing with parallel runs against the FMI operational HIRLAM for a period of several months, from summer 2003 to winter 2004. A couple of bugs and shortcomings in the RCR system were uncovered and consequently fixed. On 2 February 2004, the RCR (V621) suite gained the operational status at FMI. Since then model products have been transferred to ECMWF (ECFS system) on near-real-time basis, thus being made available for the whole HIRLAM community.

The performance of the RCR system has been validated by means of traditional verification methods, and compared against the operational FMI HIRLAM system. The performance of the RCR system turned out to be of equal quality in summer and early fall. The verification scores for winter, however, suggest that the RCR system is slightly poorer as regards p_{msl} and V_{10m} . The RCR system and the old FMI operational ATX system both have a considerable negative p_{msl} bias over eastern Europe, with RCR being slightly more negatively biased. This negative bias is most probably associated with the HIRLAM model's inability to fill occluding cyclones. Furthermore, the RCR system also shows larger rms errors in p_{msl} . The RCR system has a larger positive bias in V_{10m} than ATX. Both RCR and ATX systems show large - up to 8°C - positive T_{2m} bias in high latitudes. A closer study revealed that this T_{2m} bias is very serious in temperatures below -15°C: for the observed T_{2m} of -30°C the bias in the predicted T_{2m} can be as large as +15°C. The model-generated bias is also reflected in the T_{2m} analysis: observations are rejected in the analysis due to too large a deviation between the background value and the observation, with the erroneous, positively biased background value going into the analysed field.

A comprehensive tool package for monitoring and evaluating the RCR system has been developed and implemented as reported in Eerola (2004) and Kangas (2004). This WEB-based monitoring system will be made accessible for the whole HIRLAM community.

References

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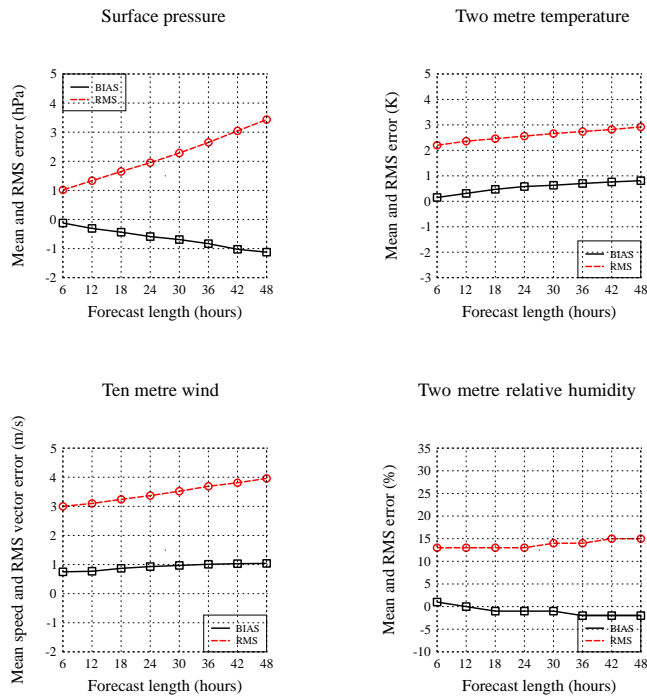


Figure 1: Observation verification statistics for ATX forecasts in February 2004. Meteorological parameters: p_{msl} (top left), T_{2m} (top right), V_{10m} (bottom left) and RH_{2m} (bottom right). Bias is indicated with squares, rms error with circles.

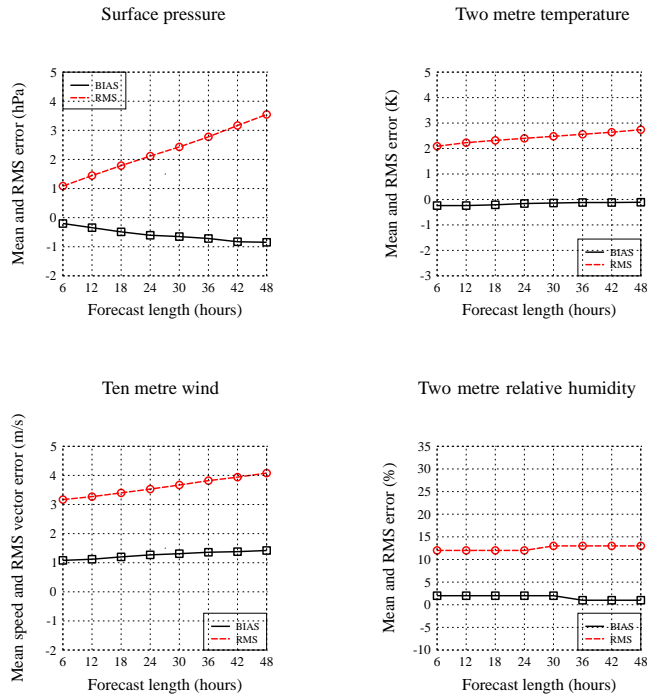


Figure 2: Observation verification statistics for V621 forecasts in February 2004. Meteorological parameters: p_{msl} (top left), T_{2m} (top right), V_{10m} (bottom left) and RH_{2m} (bottom right). Bias is indicated with squares, rms error with circles.

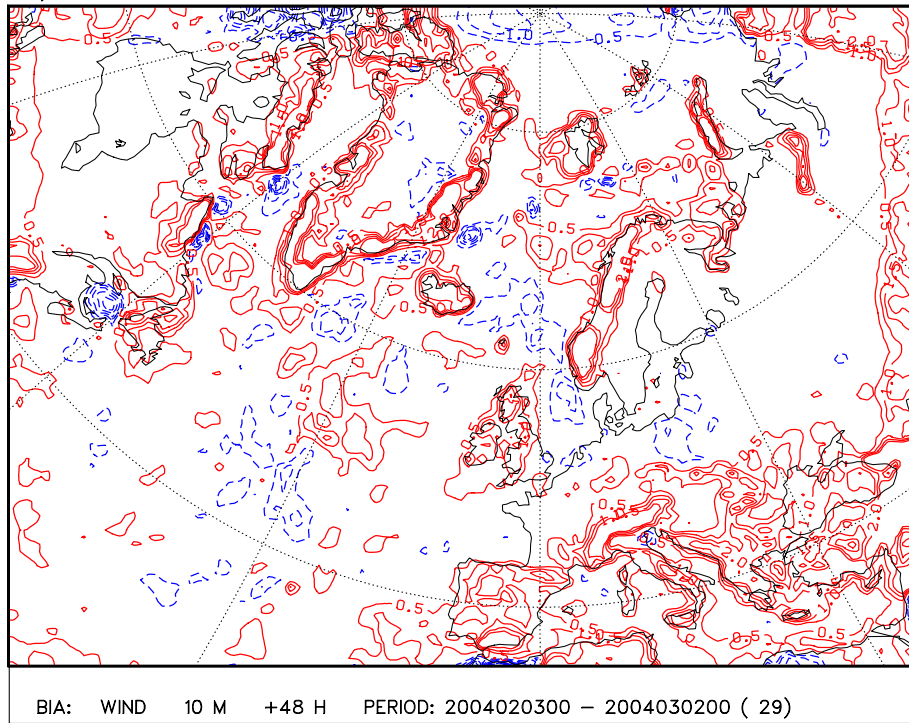


Figure 3: Systematic difference between V621 (interpolated to ATX grid) and ATX 48 h V_{10m} forecasts, starting from 00 UTC, for February 2004. Contour interval: 0.5 m/s. The zero isoline not plotted, negative values indicated with dashed lines.

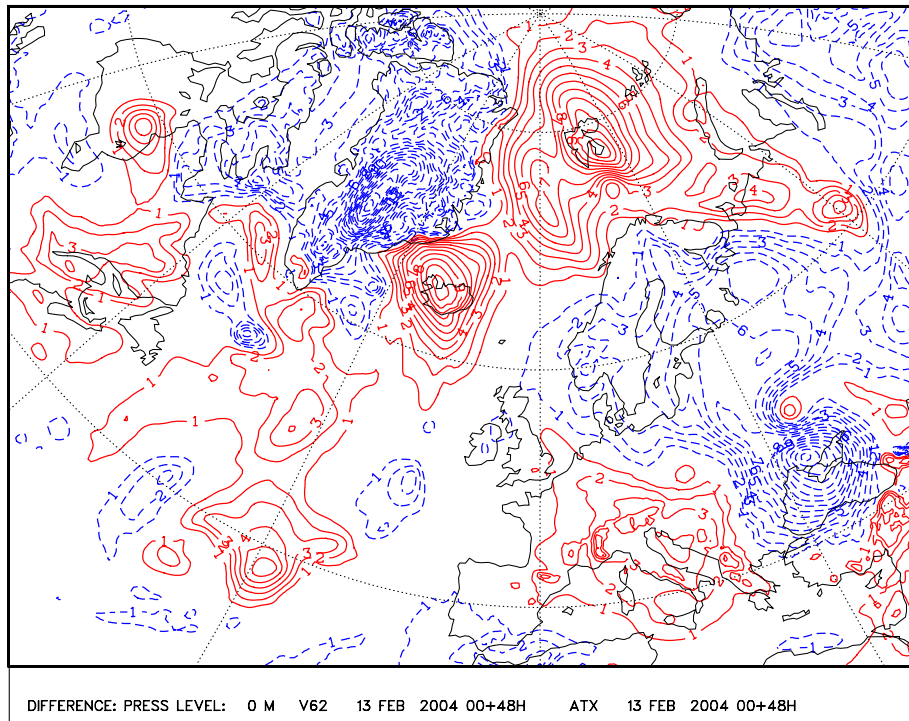


Figure 4: Difference between V621 (interpolated into ATX grid) and ATX 48 h p_{msl} forecasts, starting from 13 February 2004, 00 UTC. Contour interval: 1 hPa. The zero isoline not plotted, negative values indicated with dashed lines.

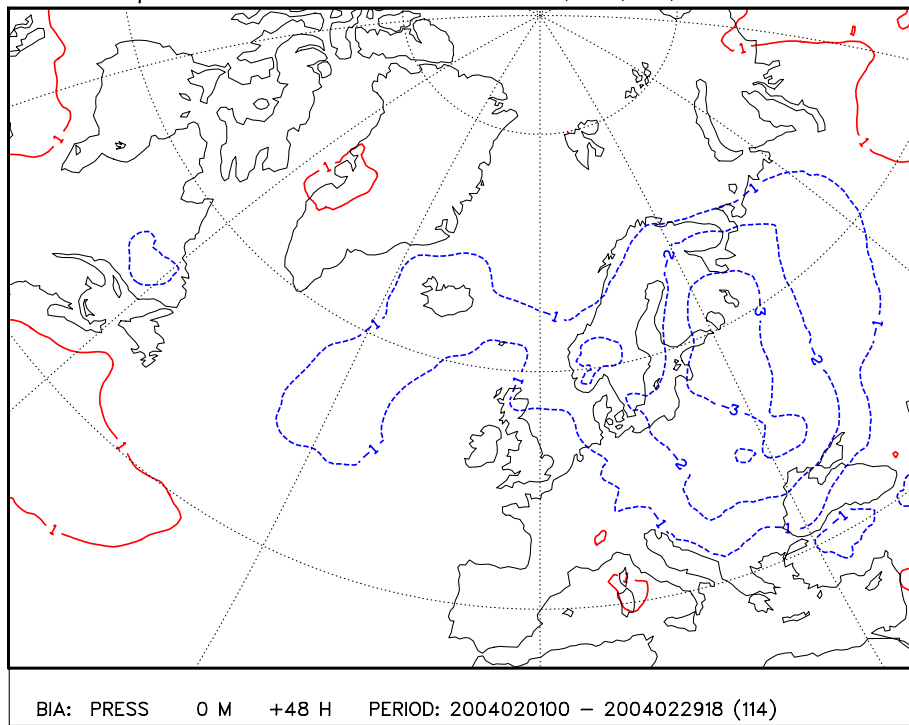


Figure 5: Bias in 48 h ATX p_{msl} forecasts for February 2004. Contour interval: 1 hPa. The zero iseline not plotted, negative values indicated with dashed lines.

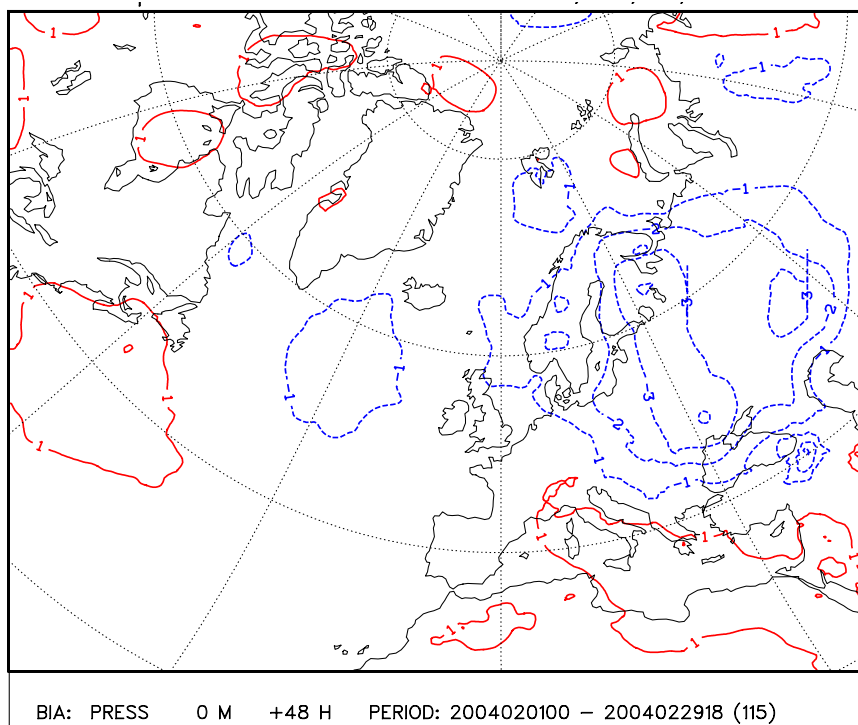


Figure 6: Bias in 48 h V621 p_{msl} forecasts for February 2004. Contour interval: 1 hPa. The zero iseline not plotted, negative values indicated with dashed lines.

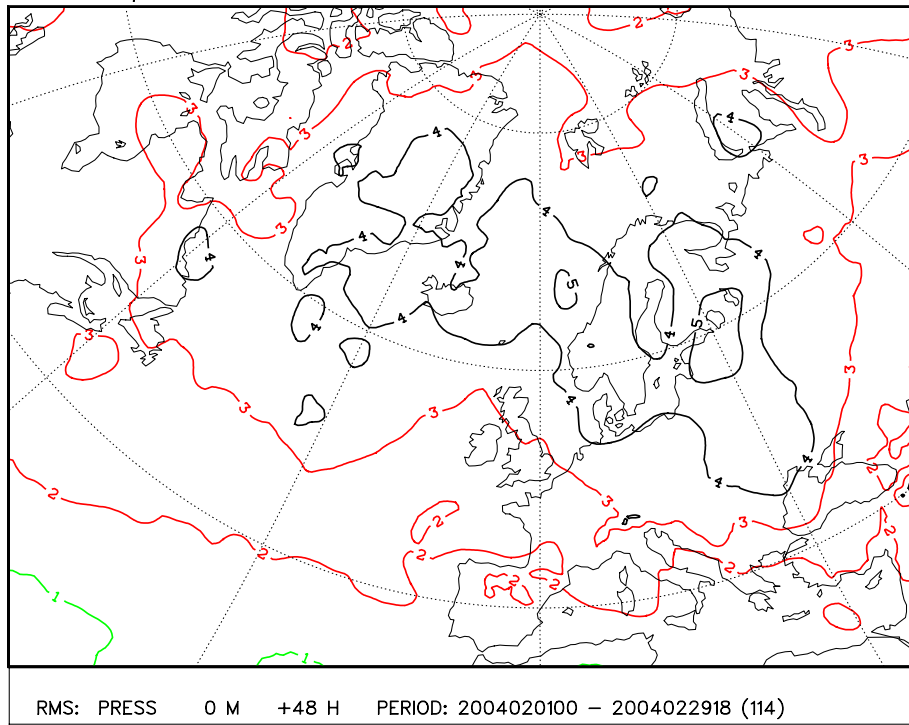


Figure 7: *Rms error in 48 h ATX p_{msl} forecasts for February 2004. Contour interval: 1 hPa.*

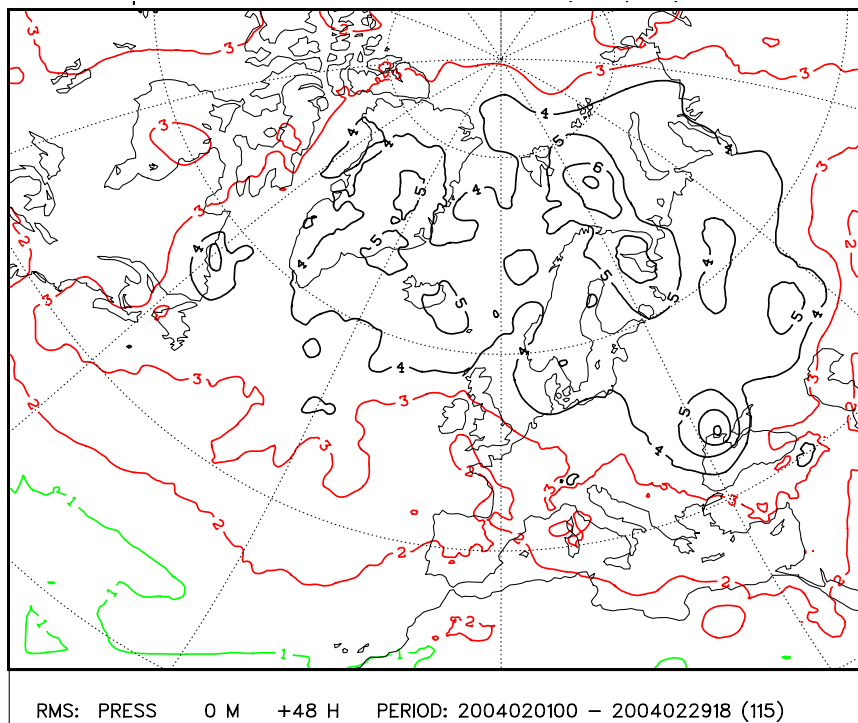


Figure 8: *Rms error in 48 h V621 p_{msl} forecasts for February 2004. Contour interval: 1 hPa.*

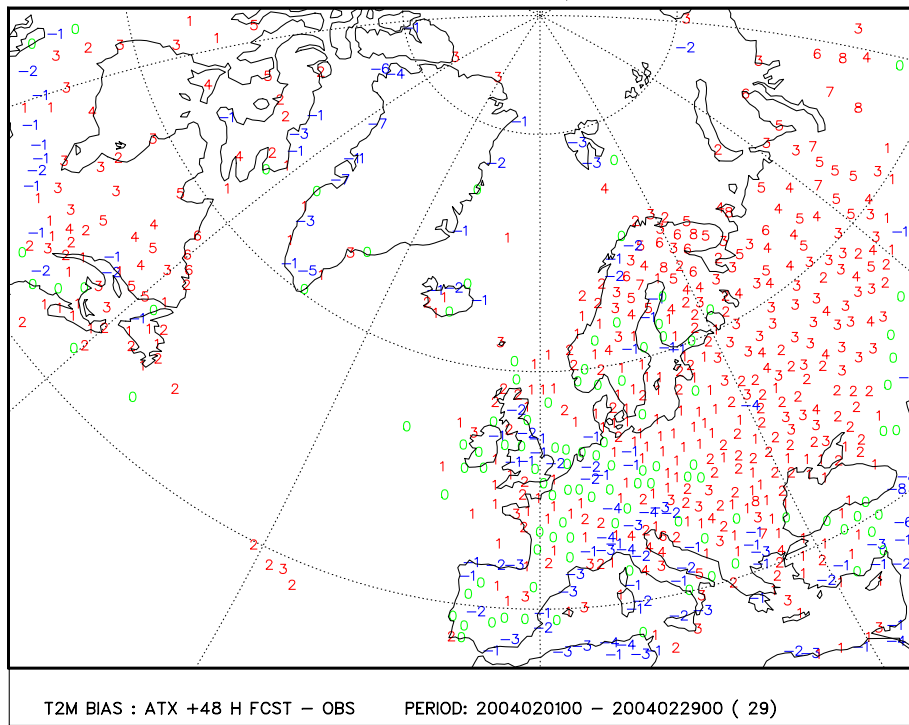


Figure 9: T_{2m} bias (calculated against observations) in 48 h ATX forecasts valid at 00 UTC in February 2004.

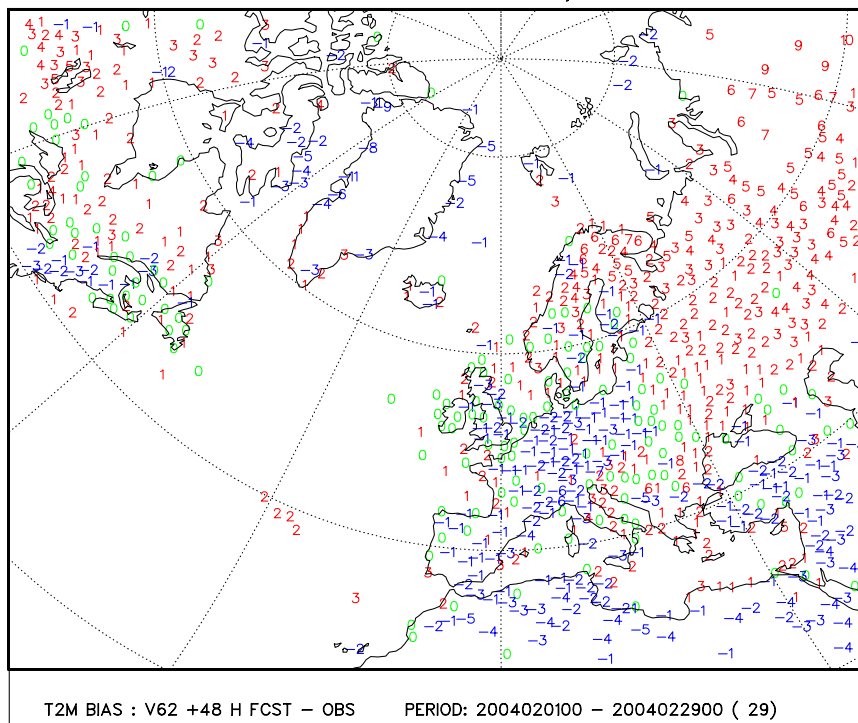


Figure 10: T_{2m} bias (calculated against observations) in 48 h V621 forecasts valid at 00 UTC in February 2004.

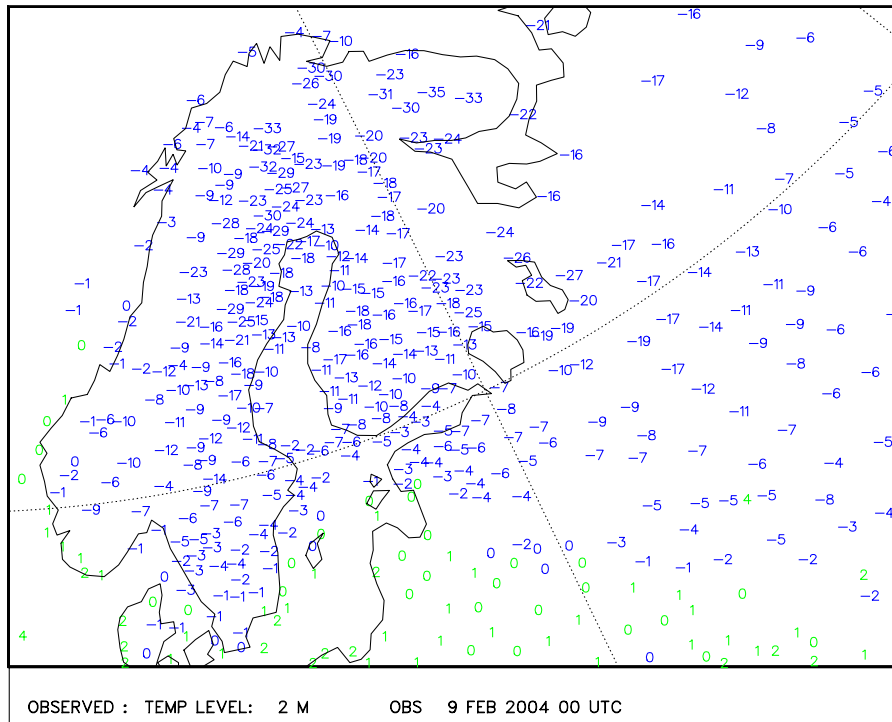


Figure 11: Observed T_{2m} in northern Europe on 9 February 2004 at 00 UTC.

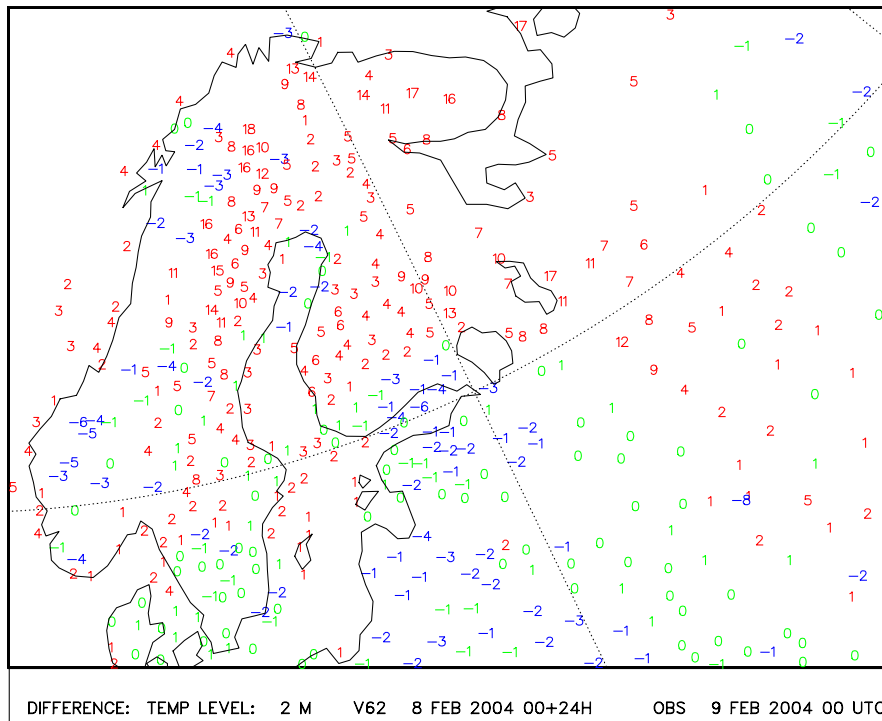


Figure 12: T_{2m} forecast error in the 24 h V621 forecast valid on 9 February 2004 at 00 UTC.

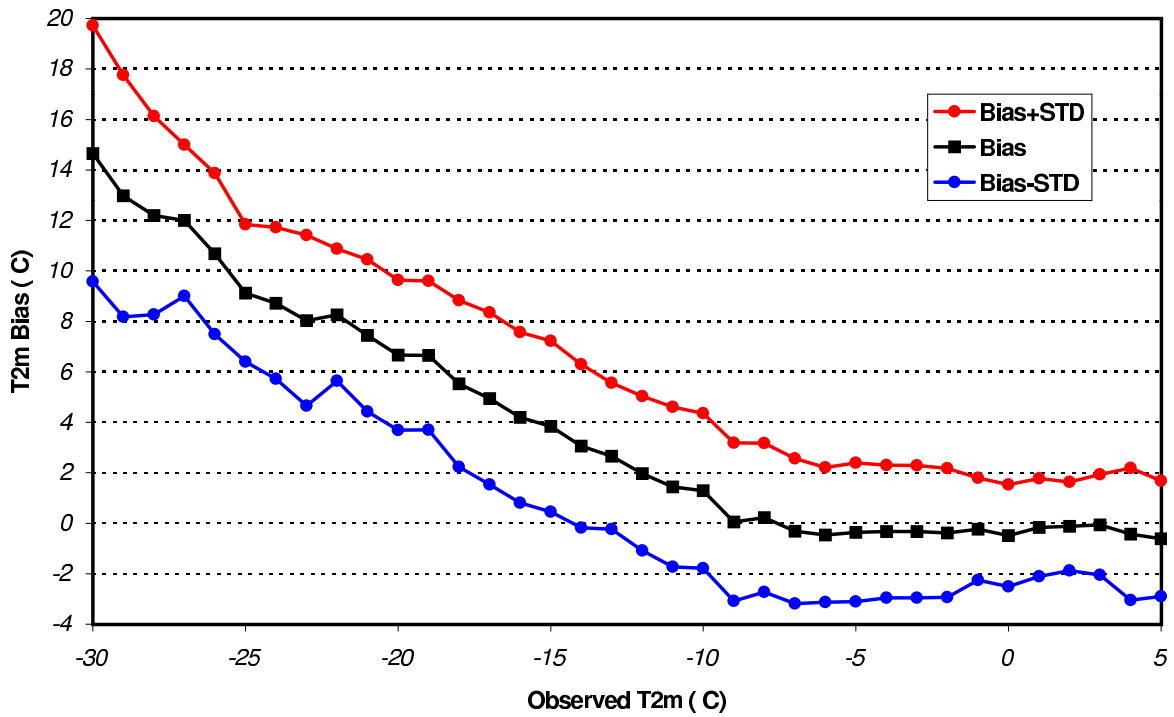


Figure 13: T_{2m} bias in HIRLAM V621 48 h forecasts, as a function of the observed T_{2m} , for January 2004 in Scandinavia and northern Russia. Bias is indicated with squares, and bias \pm one standard deviation with circles.

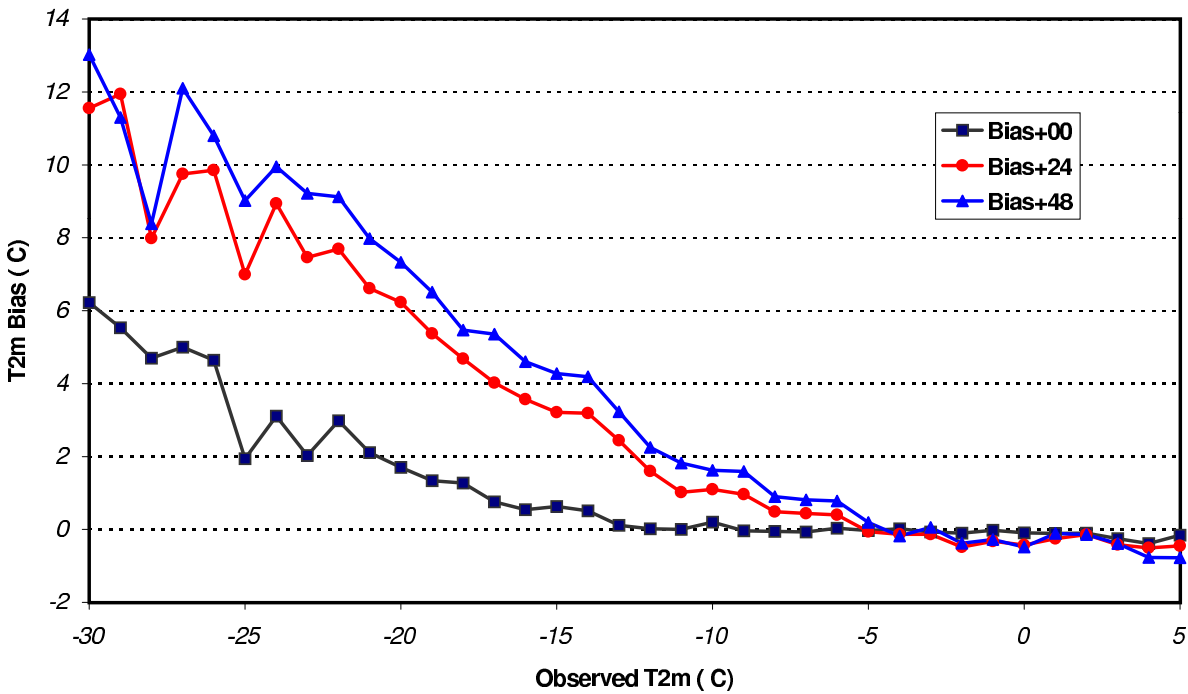


Figure 14: T_{2m} bias in HIRLAM V621 analyses (squares), 24 h (circles) and 48 h (triangles) forecasts, as a function of the observed T_{2m} , for February 2004 in Scandinavia and northern Russia.