# Tests with the HIRLAM 6.3.5 version - comparison to some earlier versions and RCR

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25th February 2005

## 1 Introduction

Several updates for the HIRLAM system have been developed recently, and two new versions, 6.3.4 and 6.3.5, have been introduced. Furthermore, so-called FAK (First Aid Kit) corrections were introduced in summer 2004. These HIRLAM versions have been tested for four different months representing different seasons, and compared with each other and against the operational RCR at FMI. The emphasis in the tests has been in evaluation of the 6.3.5 version, which should be the next reference system and therefore the basis for the next RCR system.

## 2 Test runs

In the following, the test runs are shortly described:

**FAK (Hirlam 6.3.3) :**

- $0.3°$ horizontal resolution, 40 levels in the vertical
- $256 \times 186$ grid points
- 6 h data assimilation cycle
- Lateral boundary conditions : ECMWF analyses with 6 h temporal resolution
- Physics changes compared to Reference $\beta$ 6.3.3 : for turbulence (CBR) and for roughness length of heat and momentum
- 48 h forecasts from 00 and 12 UTC analyses

**R64 (Hirlam 6.3.4) :**

- $0.3°$ horizontal resolution, 40 levels in the vertical
- $256 \times 186$ grid points
- 6 h data assimilation cycle
- Lateral boundary conditions : ECMWF analyses with 6 h temporal resolution

- Reference HIRLAM $\beta$ 6.3.4
- 48 h forecasts from 00 and 12 UTC analyses

**E64 (Hirlam 6.3.4) :**

- 0.3° horizontal resolution, 40 levels in the vertical
- 256 × 186 grid points
- 6 h data assimilation cycle
- Lateral boundary conditions : ECMWF analyses with 6 h temporal resolution
- Physics changes compared to Reference $\beta$ 6.3.4 : soil freezing modifications by E. Rodriquez
- 48 h forecasts from 00 and 12 UTC analyses

**R65 (Hirlam 6.3.5) :**

- 0.3° horizontal resolution, 40 levels in the vertical
- 256 × 186 grid points
- 6 h data assimilation cycle
- Lateral boundary conditions : ECMWF analyses with 6 h temporal resolution
- Reference HIRLAM $\beta$ 6.3.5
- 48 h forecasts from 00 and 12 UTC analyses

In addition, the test runs are compared against the RCR at FMI, which can be briefly described as follows:

**RCR (Hirlam 6.2.1) :**

- 0.2° horizontal resolution, 40 levels in the vertical
- 438 × 336 grid points
- 3 h data assimilation cycle
- Lateral boundary conditions : ECMWF 0.2° forecast frames received 4 times a day, with 3 h temporal resolution
- Reference HIRLAM 6.2.1 with some modifications, as the bug in diagnosis of the ice cover from the analysed SST field corrected (Järvenoja, 2004a)
- Forecast length : 54 h for main synoptic times

The test runs have been carried out for four different months representing different seasons. The months are: February, April and July 2004, and November 2001. Different experiments do not cover all these months. The coverage of experiments is given in the following:

- February 2004 : R65, RCR
- April 2004 : FAK, R64, E64, R65, RCR
- July 2004 : FAK, R65, RCR
- November 2001 : R64, R65

# 3 Results

In the following, some results for each month will be presented.

## 3.1 February 2004

For February 2004, only R65 experiment was run and it will be compared to RCR. Figure 1 shows the observation verification scores (Scandinavian stations only) of surface variables for R65 and RCR. Mean-sea-level pressure ($p_{msl}$) scores of RCR show a serious negative bias as was discussed earlier in Järvenoja (2004a). Negative bias exceeds 2 hPa in 48 h forecasts. The situation is different in R65: bias is slightly positive. R65 also results in a smaller rms error, but this result must be taken with care because R65 has analysed boundaries whereas RCR uses forecast boundaries. The differences in the 10-metre wind ($V_{10m}$) scores are small, with both R65 and RCR showing a positive bias of 0.5-1.0 m/s. The 2-metre temperature ($T_{2m}$) scores show that RCR had some positive bias, while R65 has practically no bias except in the daytime (12 and 36 h), when bias of the order of -1°C is seen. The 2-metre relative humidity ($RH_{2m}$) scores indicate that a positive bias is slightly larger in R65 than in RCR.

Figures 2 and 3 demonstrate the geographical distribution of the $p_{msl}$ bias in 48 h forecasts in February 2004 for RCR and R65, respectively. A large negative bias is seen over continental Europe in RCR (Fig. 2). The picture is much different in R65 as Fig. 3 shows: a negative bias is much reduced, even though some negative bias is left close to the Black Sea. The smaller bias in R65 compared to RCR is due to the rotated surface stress vector and related CRB modifications, as the test runs for February 2004 by Järvenoja (2004b) revealed.

Figures 4 and 5 depict the geographical distribution of the $T_{2m}$ bias on station basis in February 2004 (48 h forecasts valid at 00 UTC) for RCR and R65, respectively. In northern latitudes, in Scandinavia and northern Russia as well as in northern America, a considerable positive bias of up to 8-9°C dominates in RCR (Fig. 4), as was earlier reported by Järvenoja (2004a). Figure 5 shows that the positive bias of high latitudes is considerably smaller in R65 than in RCR, which is due to introduction of modified water vapour saturation (ESAT) tables (see, Järvenoja, 2005), and due to modified roughness length of heat.

As a whole, R65 performs better than RCR in February 2004, when RCR suffered from serious $p_{msl}$ and $T_{2m}$ bias problems.

### 3.2 April 2004

Several experiments were run for April 2004. In the following, R64, E64 and R65 will be compared to RCR. Figures 6 and 7 show observation verification scores (Scandinavian stations only) of surface variables for R64 together with RCR and R65 together with E64, respectively.

Figure 6 shows that the $p_{msl}$ bias is close to zero in both RCR and R64.The rms error of R64 is smaller, but it should be kept in mind that R64 uses analysed boundaries. Figure 7 reveals that the $p_{msl}$ bias is very small in E64 and R65, and similar to that of R64. Furthermore, it can be seen that the rms error is smallest in R65 (among the new experiments). The $V_{10m}$ scores are very similar in all experiments (R64, E64, R65) and in RCR.

RCR suffered from a serious negative daytime $T_{2m}$ bias as reported in Järvenoja (2005), and this problem is clearly seen also in Fig. 6. The daytime (12 and 36 h) bias in Scandinavia is about -2°C, whereas the nighttime (24 and 48 h) bias is close to zero. R64 and E64 show a similar diurnal bias behaviour, but the temperature in R64 and E64 is throughout somewhat (0.5-1°C) higher, meaning e.g., that the negative daytime bias is not as serious as in RCR. It should be noted that there is no difference between E64 and R64. The E64 modifications for soil freezing were developed to reduce the excessive evaporation in Nordic spring conditions, in which evaporation is still rather small in nature due to frozen soil and lack of grass on the ground and leaves on trees. It is obvious that the E64 modifications do not work (yet) as they should. In R65, $T_{2m}$ is lower than in R64 and E64, and the bias is thus closer to that of RCR.

The positive $RH_{2m}$ bias is large, close to 20% in the daytime, in RCR (Fig. 6). The positive bias is considerably reduced from that value in case of R64 (Fig. 6) and E64 (Fig. 7), but is then slightly increased in case of R65 (Fig. 7) compared to R64 and E64.

The complicated $T_{2m}$ bias structure in spring is demonstrated in Fig. 8, showing the daytime (12 UTC) bias in 48 h RCR forecasts, for April 2004. The winter-type positive bias prevails in high latitudes, in northern America and northern Russia. But, in Scandinavia, Estonia and Russia east and southeast of Finland, there is a negative $T_{2m}$ bias of a few degrees. In western and central Europe, the bias is close to zero or slightly positive. The negative daytime bias in Nordic areas is replaced by a positive nighttime bias (not shown). This means that the diurnal cycle in the predicted $T_{2m}$ is damped, which is an indication of excessive cloud amount, as reported by Järvenoja (2005). The $T_{2m}$ bias is somewhat different in R64 and E64 (Figs. 9 and 10). The negative bias in Scandinavia is slightly smaller in R64 and E64 (with R64 and E64 very similar) than in RCR, as the observation verification scores in Figs 6 and 7 also suggested. In central Europe, R64 and E64 have an increased positive bias compared to RCR. Finally, Fig. 11 shows the $T_{2m}$ bias for R65, and it can be seen that the bias structure is similar to that of R64 and E64, with R65 resulting in slightly lower $T_{2m}$ than R64 and E64.

Overall, the new experiments result in slightly different forecasts, as regards $p_{msl}$ and $T_{2m}$. The springtime $T_{2m}$ problem still remains, even though slight improvements were seen in R64 (and E64). R64 (E64) and R65 had considerably smaller positive $RH_{2m}$ bias than RCR.

### 3.3 July 2004

A couple of experiments were run for July 2004. In the following, FAK and R65 will be compared to RCR. Figures 12 and 13 demonstrate observation verification scores (EWGLAM stations) of surface variables for FAK together with RCR, and R65 together with FAK, respectively. Figure 12 shows that RCR has a positive $p_{msl}$ bias that increases as a function of forecast length, reaching 1 hPa at 48 hours in the area of EWGLAM stations. FAK shows a similar feature with the bias being about half of that in RCR. R65 and FAK have very similar $p_{msl}$ scores as Fig. 13 demonstrates. The $V_{10m}$ scores reveal a clear diurnal cycle in the bias, with the bias being larger in the nighttime and in the daytime (Fig.12). RCR shows a positive $V_{10m}$ bias both at night and in the daytime, whereas FAK has a positive $V_{10m}$ bias of about 0.5 m/s at night and a negative bias of the same magnitude in the daytime. R65 and FAK scores for $V_{10m}$ are almost identical (Fig. 13).

RCR suffered from a notable negative $T_{2m}$ bias in July 2004 as verification scores in Fig. 12 reveal (also reported in Järvenoja, 2005). The negative $T_{2m}$ bias coincides with a positive $RH_{2m}$ bias, with both showing a clear diurnal cycle. The $T_{2m}$ and $RH_{2m}$ bias is much more acceptable in FAK than in RCR. There is still some bias left in both variables in FAK, and the diurnal cycle remains damped, but the average bias (of day and night) is close to zero. Figure 13 shows that R65 results in slightly lower $T_{2m}$ and higher $RH_{2m}$ than FAK.

Figures 14 and 15 depict the geographical distribution of the $p_{msl}$ bias in 48 h forecasts in July 2004 for RCR and R65, respectively. RCR shows a positive bias of a few hPa over almost the whole model domain, except Greenland. The positive bias over Europe and Russia is rather exceptional: usually a negative bias dominates here, in the area of occluding cyclones. The picture for R65 (Fig. 14) is much different. Bias values are small, only over Greenland a bias of -2 hPa can be seen.

Figures 16 and 17 show the 925 hPa temperature ($T_{925}$) bias in July 2004 for RCR and R65, respectively. Figure 16 demonstrates that a considerable negative bias in the lower troposphere dominates over land areas in RCR. A negative bias of this magnitude has not been seen in the operational HIRLAM implementations at FMI since introduction of the Savijärvi radiation scheme (1994). It is obvious that the negative lower tropospheric temperature bias is contributing to the positive $p_{msl}$ bias in RCR. Figure 17 shows that the $T_{925}$ bias in R65 is mainly small, with only locally exceeding $\pm 1°$C.

Figures 18 and 19 depict the geographical distribution of the $T_{2m}$ bias on station basis in July 2004 (48 h forecasts valid at 12 UTC) for RCR and R65, respectively. A negative bias of several degrees dominates over almost the whole model domain, except in Spain. This situation, with the $T_{2m}$ being as much as -5°C, can be considered very serious for the reputation of HIRLAM. A quick fix for the problem was developed in form of FAK corrections. These were tested by Järvenoja (2005) for July 2004 and resulted in similar, much more acceptable $T_{2m}$ bias pattern as R65 (Fig 19).

As a whole, the new experiments (FAK and R65) seem to improve the lower tropospheric temperature prediction, which is also reflected in better $p_{msl}$ forecasts. Especially, the serious $T_{2m}$ bias of RCR is avoided. Furthermore, the long-lasting bias in $V_{10m}$ is clearly reduced.

### 3.4 November 2001

For November 2001, experimental test runs with R64 and R65 were carried out. Figure 20 demonstrates observation verification scores (EWGLAM stations) of surface variables for R65 and R64. The scores for $p_{msl}$ are very similar for R65 and R64. At longer forecast lengths R65 has slightly larger rms error compared to R64. The $V_{10m}$ show that R65 has a marginally smaller positive bias than R64. As regards $T_{2m}$, R64 shows a small positive bias, whereas the R65 bias is slightly negative. The $RH_{2m}$ bias is negative in both R64 and R65, but less negative in R65 than in R64.

Figures 21 and 22 show the geographical distribution of the $p_{msl}$ bias in 48 h forecasts in November 2001 for R64 and R65, respectively. The bias structure is similar in both R64 and R65, with a positive bias dominant in high latitudes and a negative bias present over the Atlantic west of the British Isles and Iceland as well as in Europe west of the Black Sea. The month of November 2001 was synoptically very active with several cyclones crossing Scandinavia, and with a low pressure being located north of Scandinavia in the monthly mean map. In R65, a positive bias of high latitudes (area of the low pressure) is smaller than in R64. This is most probably due to the rotated surface stress vector in the R65 experiment.

Finally, Figs. 23 and 24 show the geographical distribution of the $T_{2m}$ bias on station basis in November 2001 (48 h forecasts valid at 12 UTC) for R64 and R65, respectively. The bias structure is similar in R64 and R65. A notable difference between R65 and R64 is the smaller positive bias over eastern Europe and Russia in R65 than in R64.

## 4 Summary

Two recent HIRLAM $\beta$ releases, 6.3.4 and 6.3.5, together with a so-called FAK version have been tested for four months representing different seasons. Results from these runs have been validated and compared with each other as well as against the operational RCR at FMI.

The experience at FMI has shown that most serious problems in RCR are related to basic surface variables such as $p_{msl}$, $V_{10m}$, $T_{2m}$ and $RH_{2m}$. Therefore, only the surface variables are used in this evaluation. In the following, the main findings from the tests are summarized, with the emphasis on what has been achieved with HIRLAM 6.3.5 compared to RCR.

The RCR system suffered from a large negative $p_{msl}$ bias (over Europe) in February 2004, during a synoptically active period. The 6.3.5 system, including the rotated surface stress vector and related CBR modifications, helped to reduce the negative bias significantly.

The long-lasting problem of the positively biased $V_{10m}$ seems to remain in HIRLAM 6.3.5 in spite of efforts to modify the CBR scheme. The $V_{10m}$ bias is somewhat reduced in summer (July 2004) compared to RCR, but in winter and autumn the positive wind bias of the order of 1 m/s still remains.

Some of serious bias problems related to $T_{2m}$ and $RH_{2m}$ are, at least partially, cured in HIRLAM 6.3.5 compared to RCR. The large positive wintertime $T_{2m}$ bias of up to 8-9°C in high latitudes is much reduced (but not completely removed) in HIRLAM 6.3.5 compared to RCR. The same positive impact on $T_{2m}$ is seen also in autumn (November 2001), when comparing HIRLAM 6.3.5 against 6.3.4. The HIRLAM 6.3.5 also helps to remove the mysterious, large negative summertime (July 2004) $T_{2m}$ bias covering almost the whole model domain in RCR. The problem of the negative daytime $T_{2m}$ bias in spring (April 2004) in Nordic areas still remains in HIRLAM 6.3.5, in spite of the fact that some of the related positive $RH_{2m}$ bias has been reduced in 6.3.5 compared to RCR.

The advantages listed above, together with the fact that no (new) serious problems were encountered in the tests covering four different seasons, favour the HIRLAM 6.3.5 $\beta$ release to be the basis for the next Reference version. Extra efforts are needed to solve the remaining problems.

# References


Järvenoja, S., 2004a: Towards the operational RCR system - results from pre-operational runs. *HIRLAM Newsletter*, **45**, 48-62.

Järvenoja, S., 2004b: Experimentation with a modified surface stress. *HIRLAM Newsletter*, **45**, 113-123.

Järvenoja, S., 2005: Problems in predicted HIRLAM $T_{2m}$ in winter, spring and summer. Proceedings of the SRNWP/HIRLAM Workshop on Surface Processes and Turbulence, SMHI, Norrköping, 15-17 September 2004, in print.

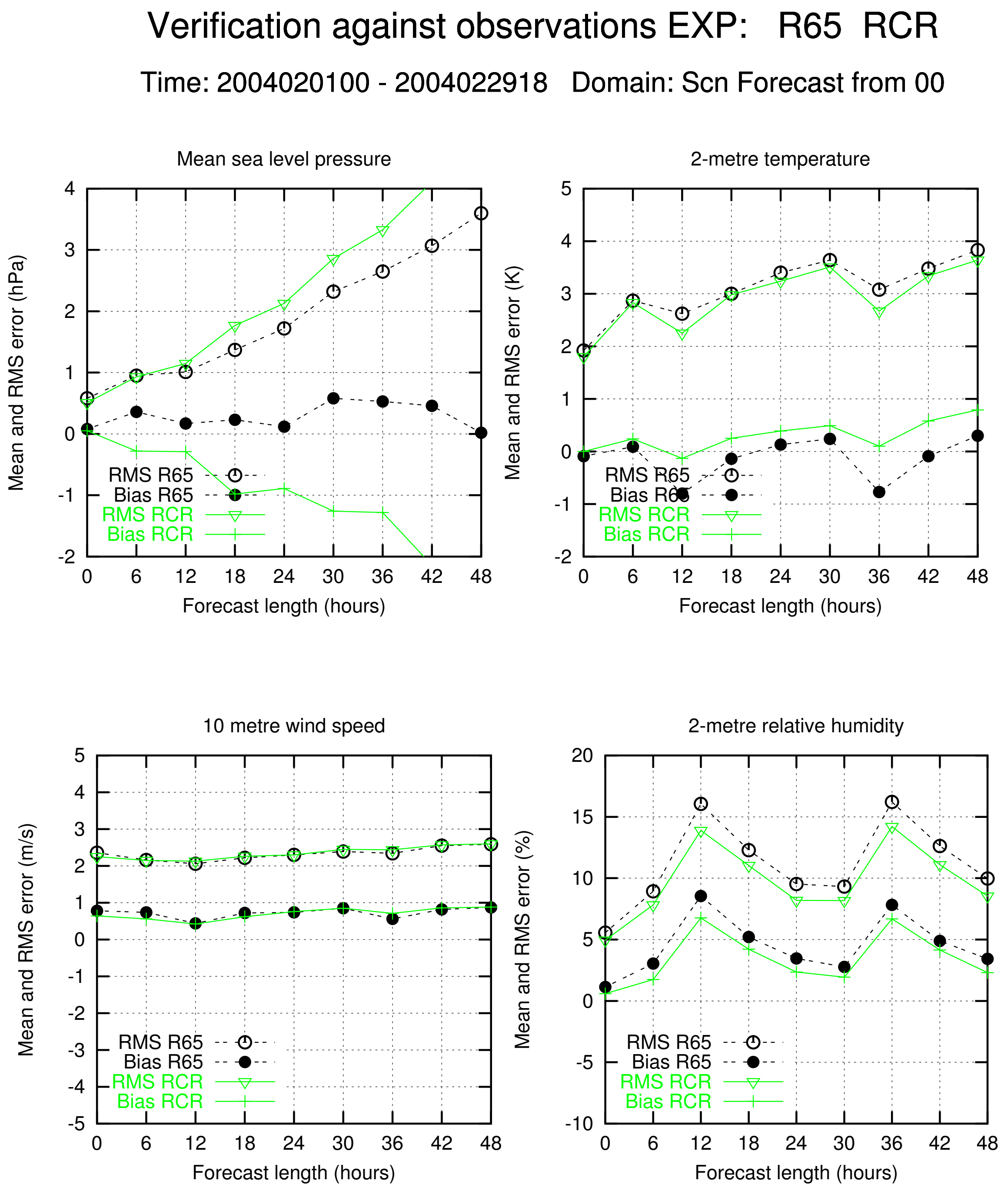


Figure 1: *Observation verification (Scandinavian stations) scores of surface pressure, 10-metre wind speed, 2-metre temperature and 2-metre relative humidity as a function of forecast length, for R65 and RCR runs in February 2004. Forecasts from 00 UTC analyses are included only.*

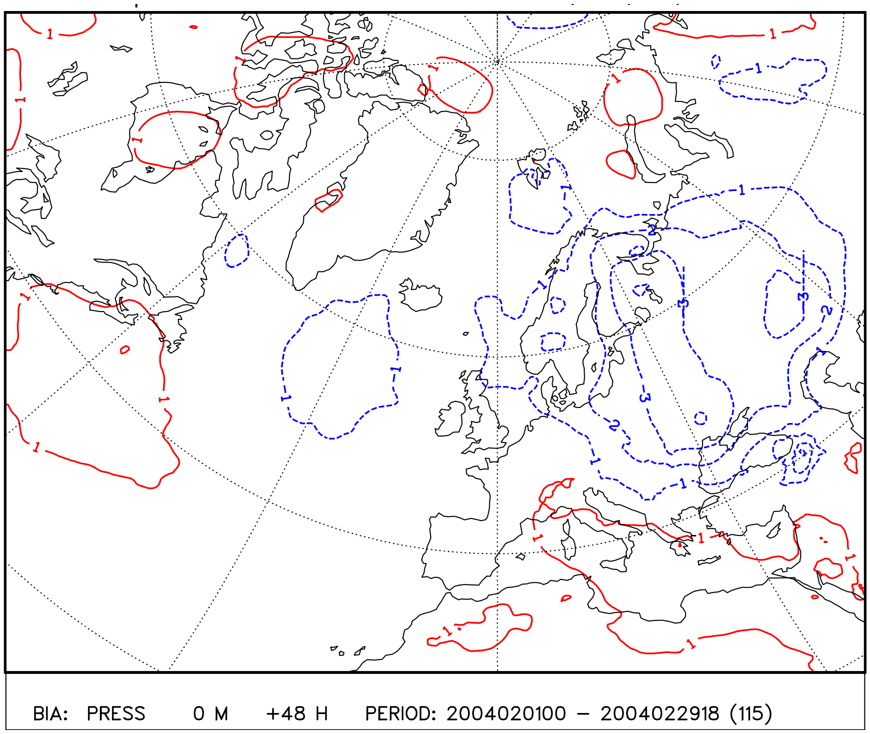


Figure 2: *$P_{msl}$ bias (forecast minus analysis) in 48 h RCR forecasts, for February 2004. Contour interval: 1 hPa. The zero isoline not plotted, negative values indicated with dashed lines.*

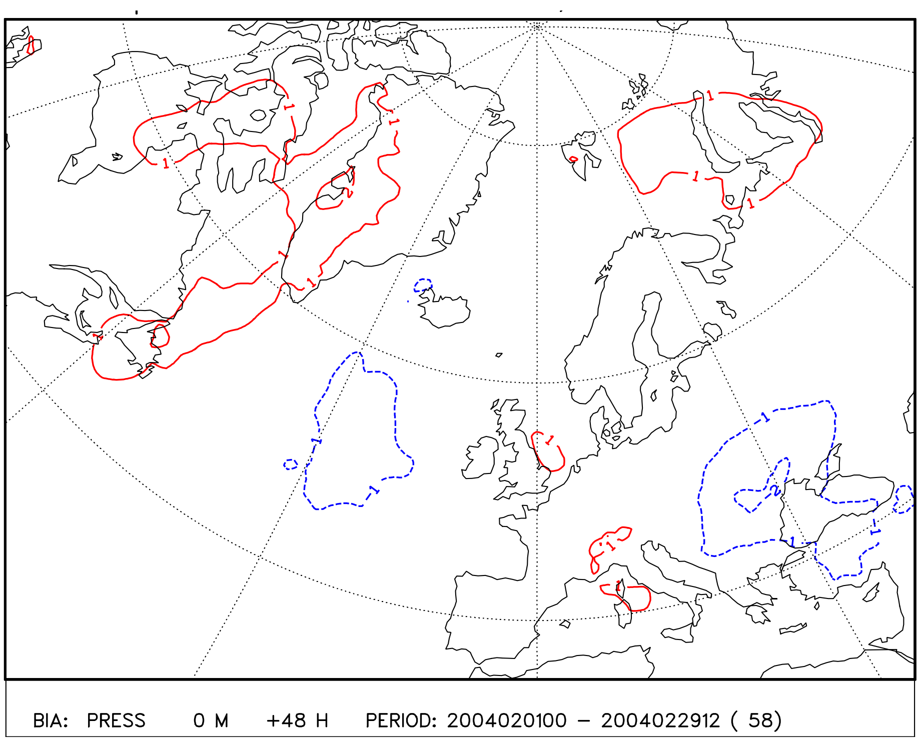


Figure 3: *$P_{msl}$ bias (forecast minus analysis) in 48 h R65 forecasts, for February 2004. Contour interval: 1 hPa. The zero isoline not plotted, negative values indicated with dashed lines.*

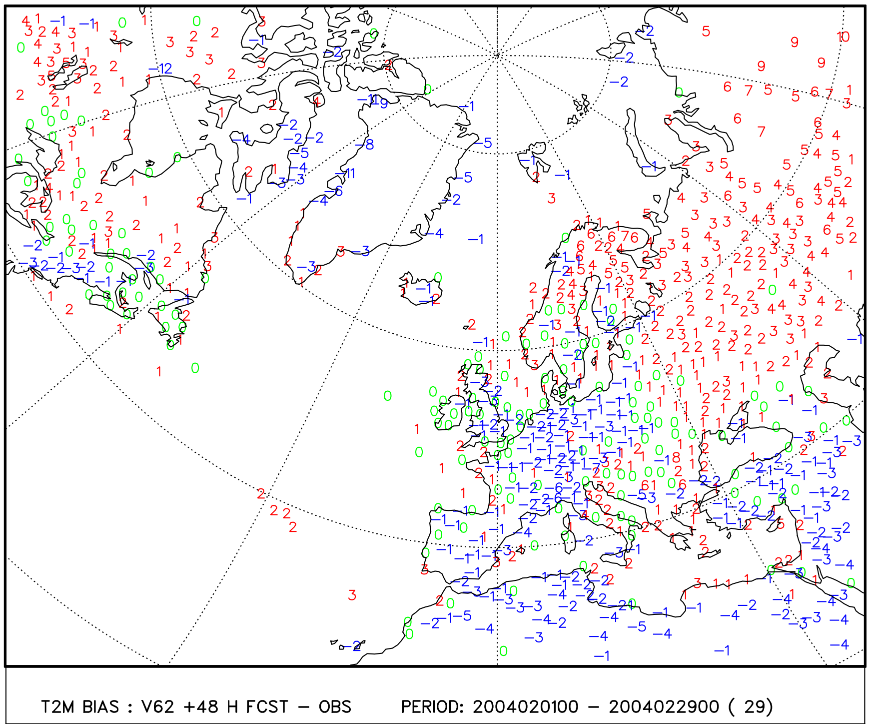


Figure 4: *$T_{2m}$ bias (calculated against observations) in 48 h RCR forecasts valid at 00 UTC, for February 2004.*

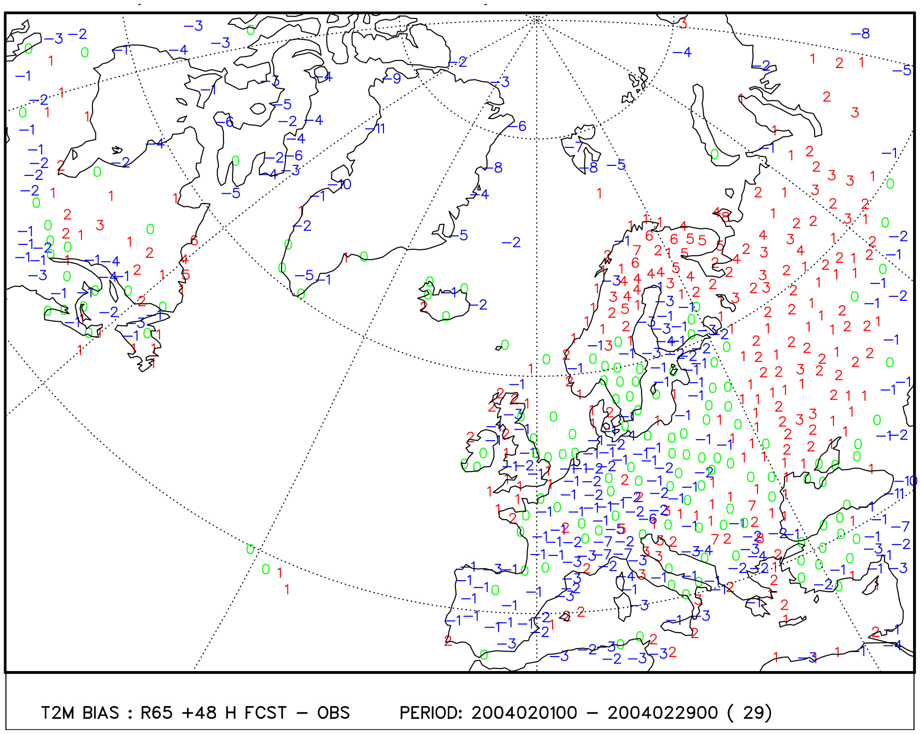


Figure 5: *$T_{2m}$ bias (calculated against observations) in 48 h R65 forecasts valid at 00 UTC, for February 2004.*

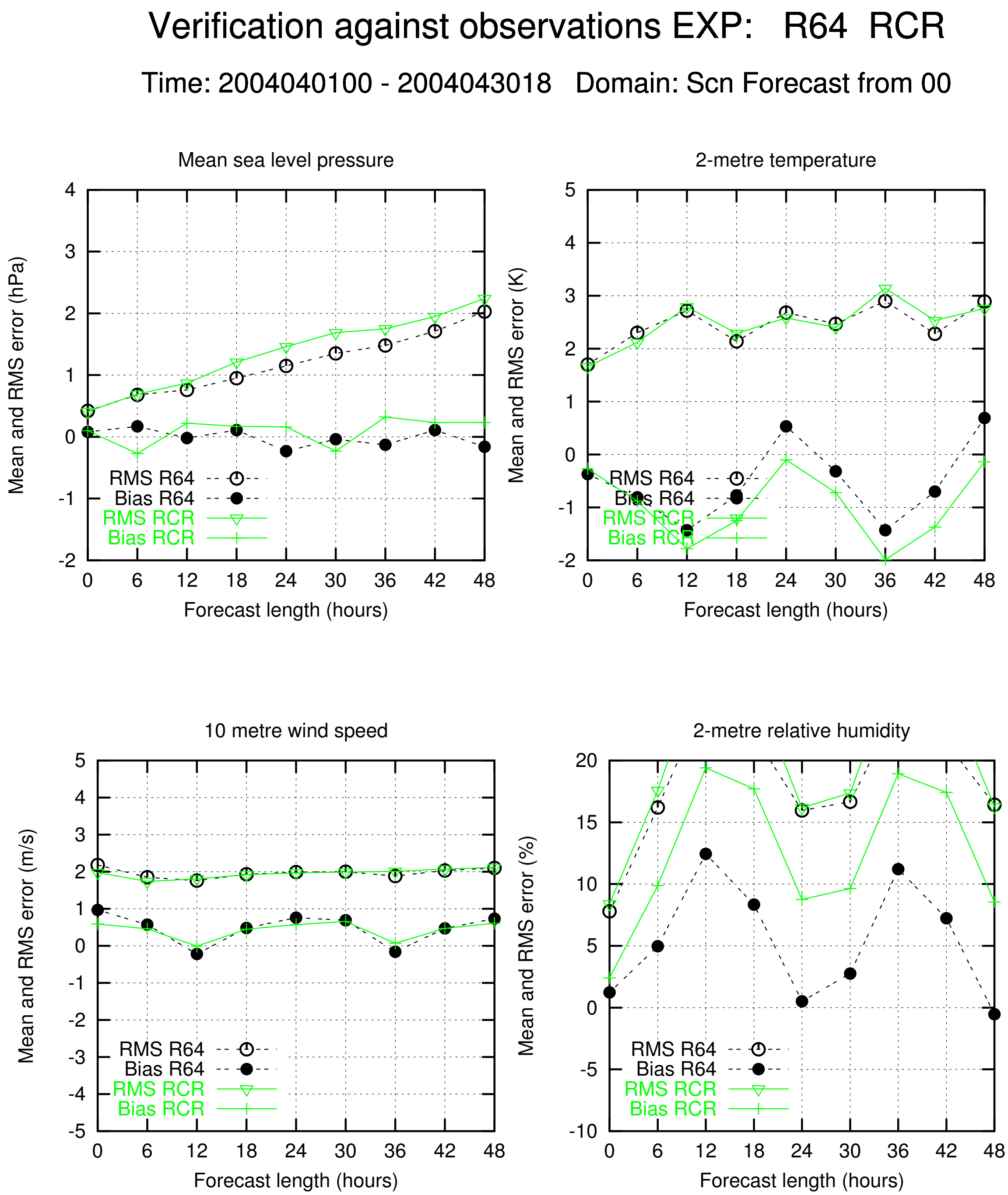


Figure 6: *Observation verification (Scandinavian stations) scores of surface pressure, 10-metre wind speed, 2-metre temperature and 2-metre relative humidity as a function of forecast length, for R64 and RCR runs in April 2004. Forecasts from 00 UTC analyses are included only.*

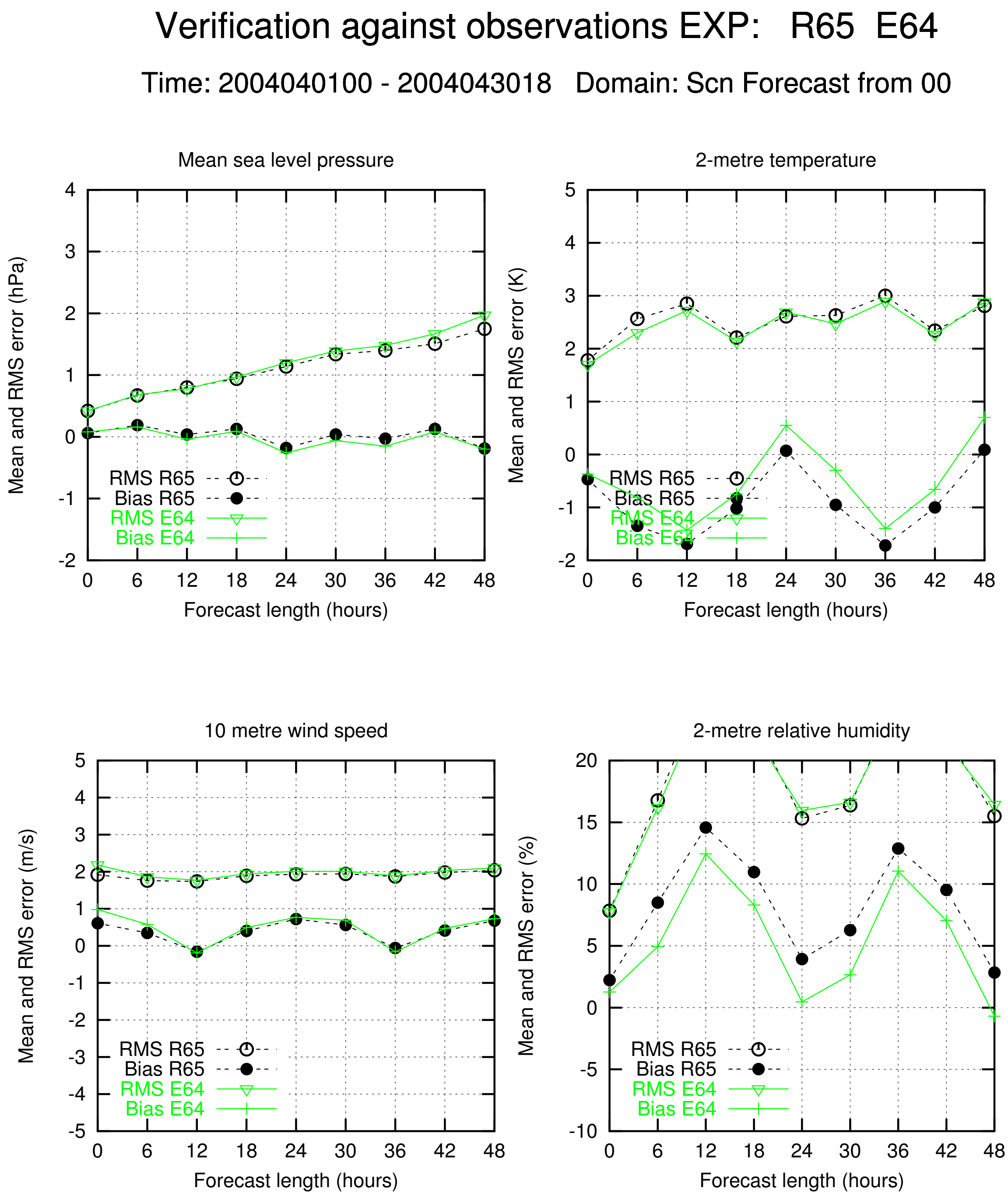


Figure 7: *Observation verification (Scandinavian stations) scores of surface pressure, 10-metre wind speed, 2-metre temperature and 2-metre relative humidity as a function of forecast length, for R65 and E64 runs in April 2004. Forecasts from 00 UTC analyses are included only.*

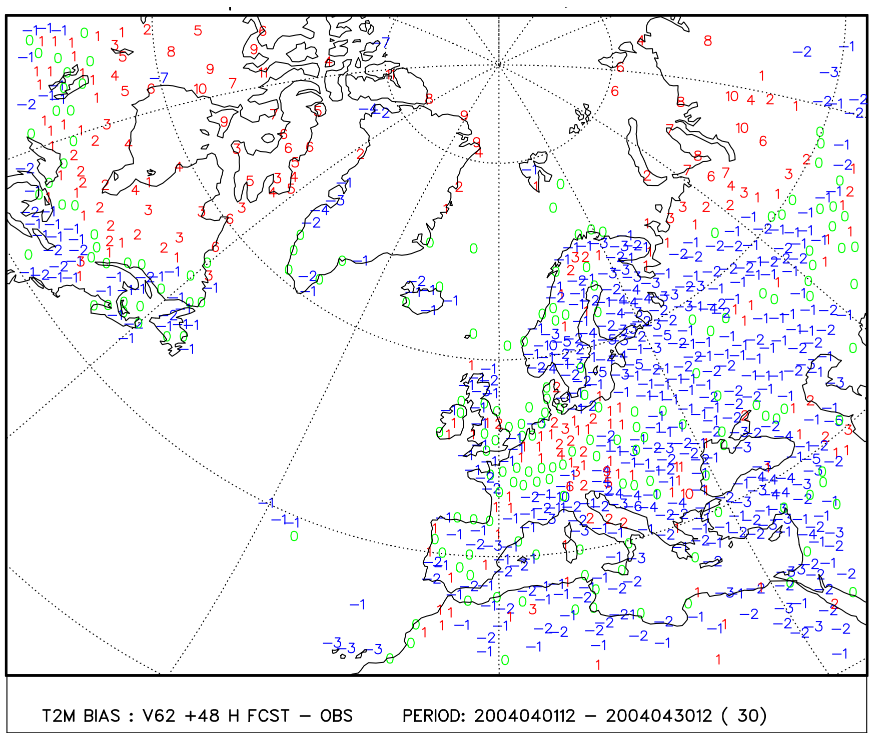


Figure 8: $T_{2m}$ *bias (calculated against observations) in 48 h RCR forecasts valid at 12 UTC, for April 2004.*

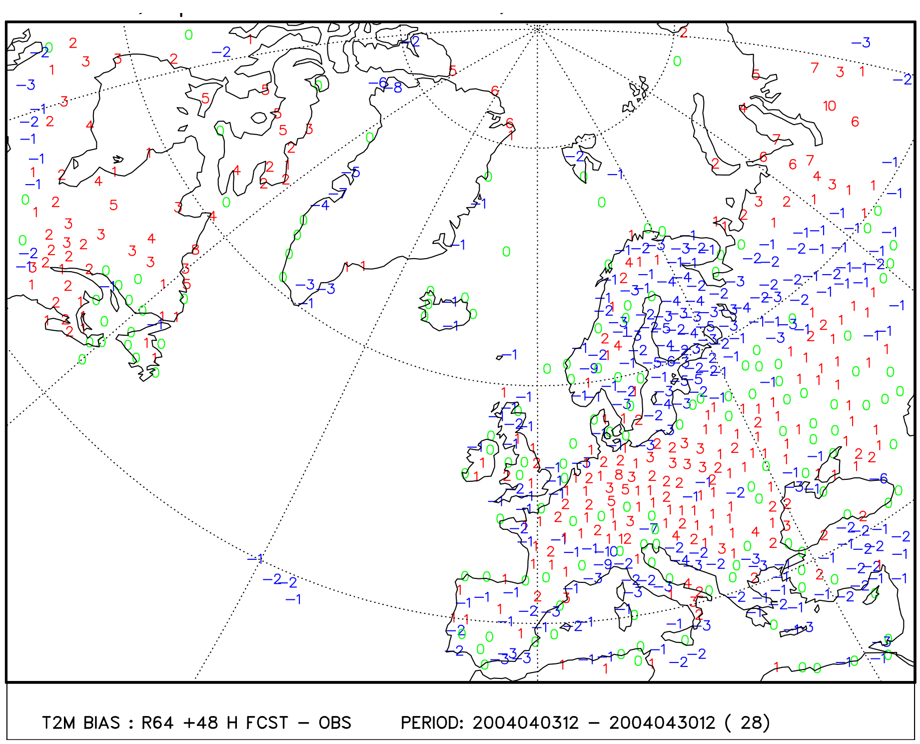


Figure 9: $T_{2m}$ *bias (calculated against observations) in 48 h R64 forecasts valid at 12 UTC, for April 2004.*

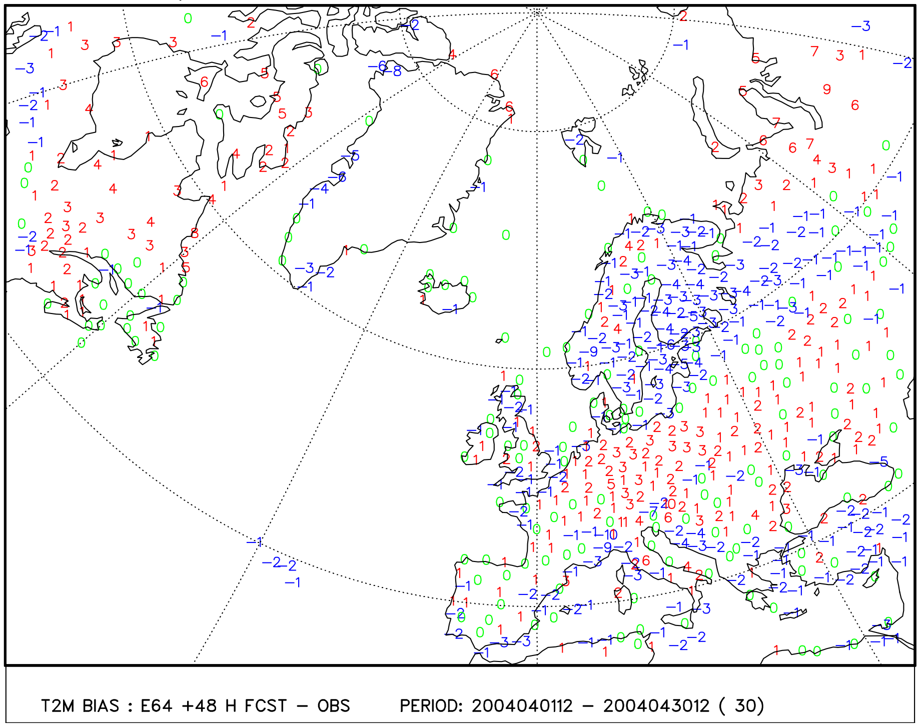


Figure 10: $T_{2m}$ *bias (calculated against observations) in 48 h E64 forecasts valid at 12 UTC, for April 2004.*

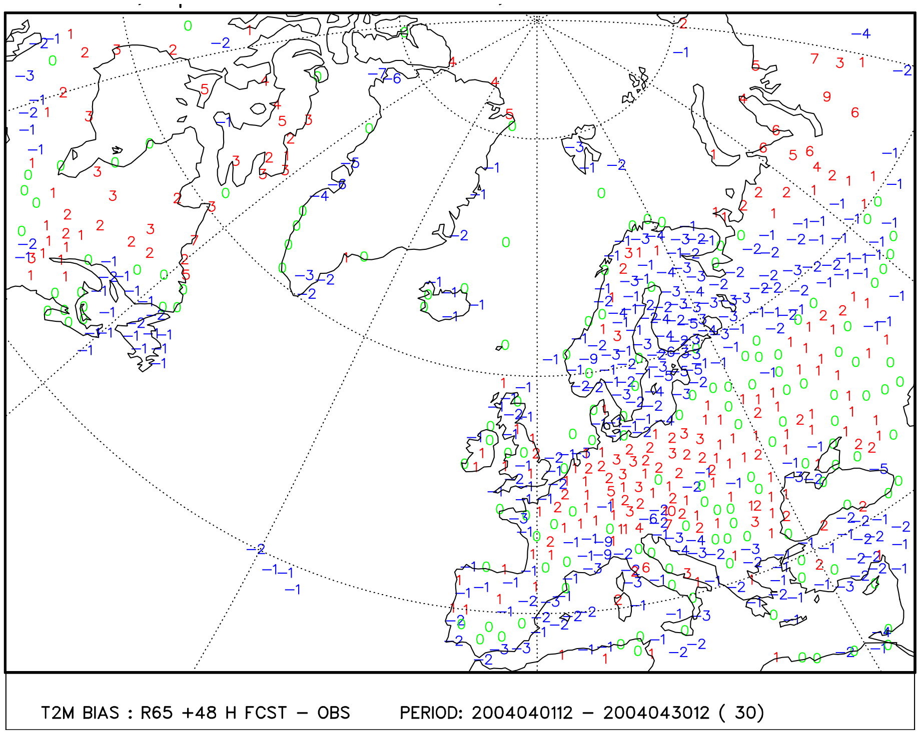


Figure 11: $T_{2m}$ *bias (calculated against observations) in 48 h R65 forecasts valid at 12 UTC, for April 2004.*

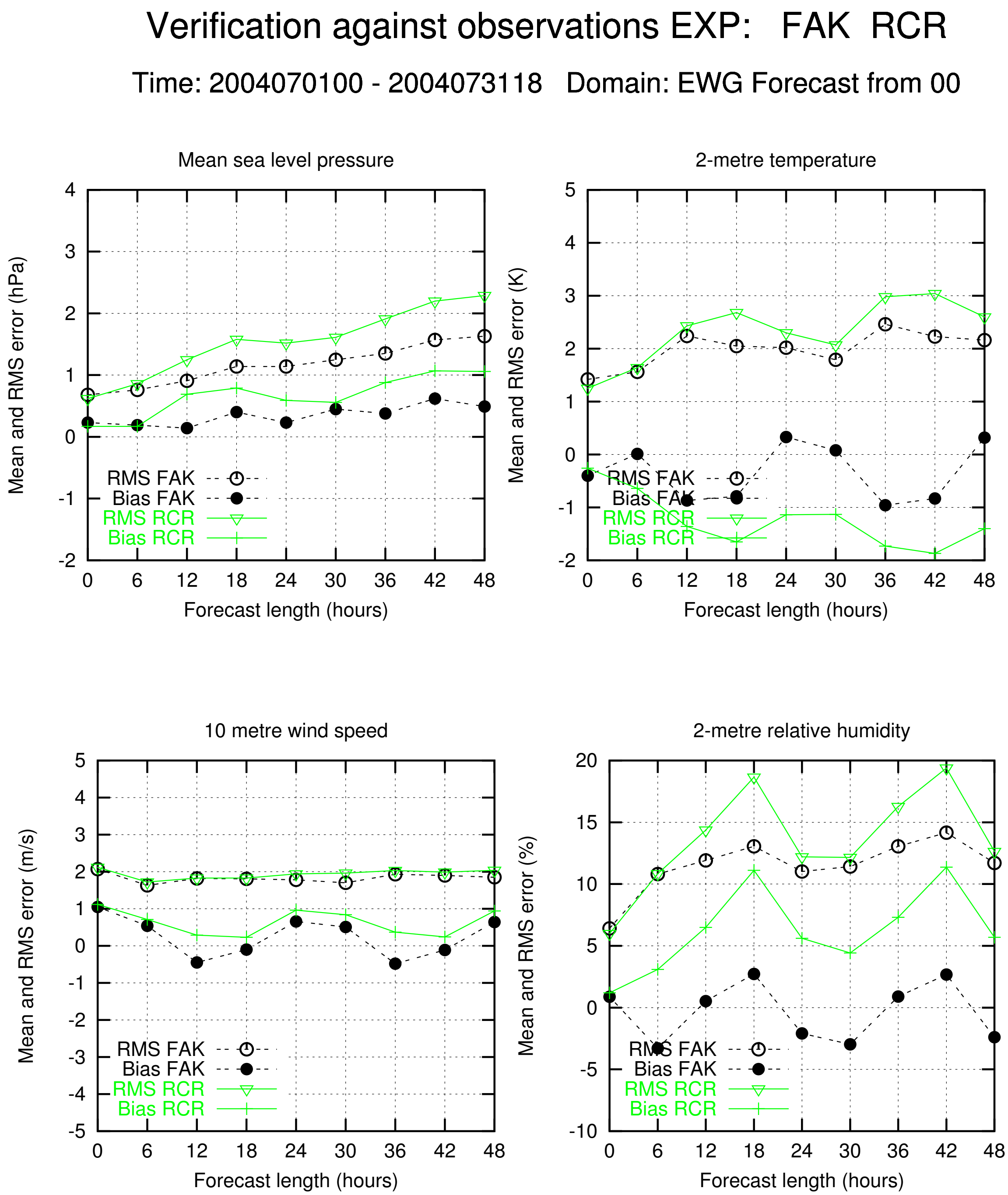


Figure 12: *Observation verification (EWGLAM stations) scores of surface pressure, 10-metre wind speed, 2-metre temperature and 2-metre relative humidity as a function of forecast length, for FAK and RCR runs in July 2004. Forecasts from 00 UTC analyses are included only.*

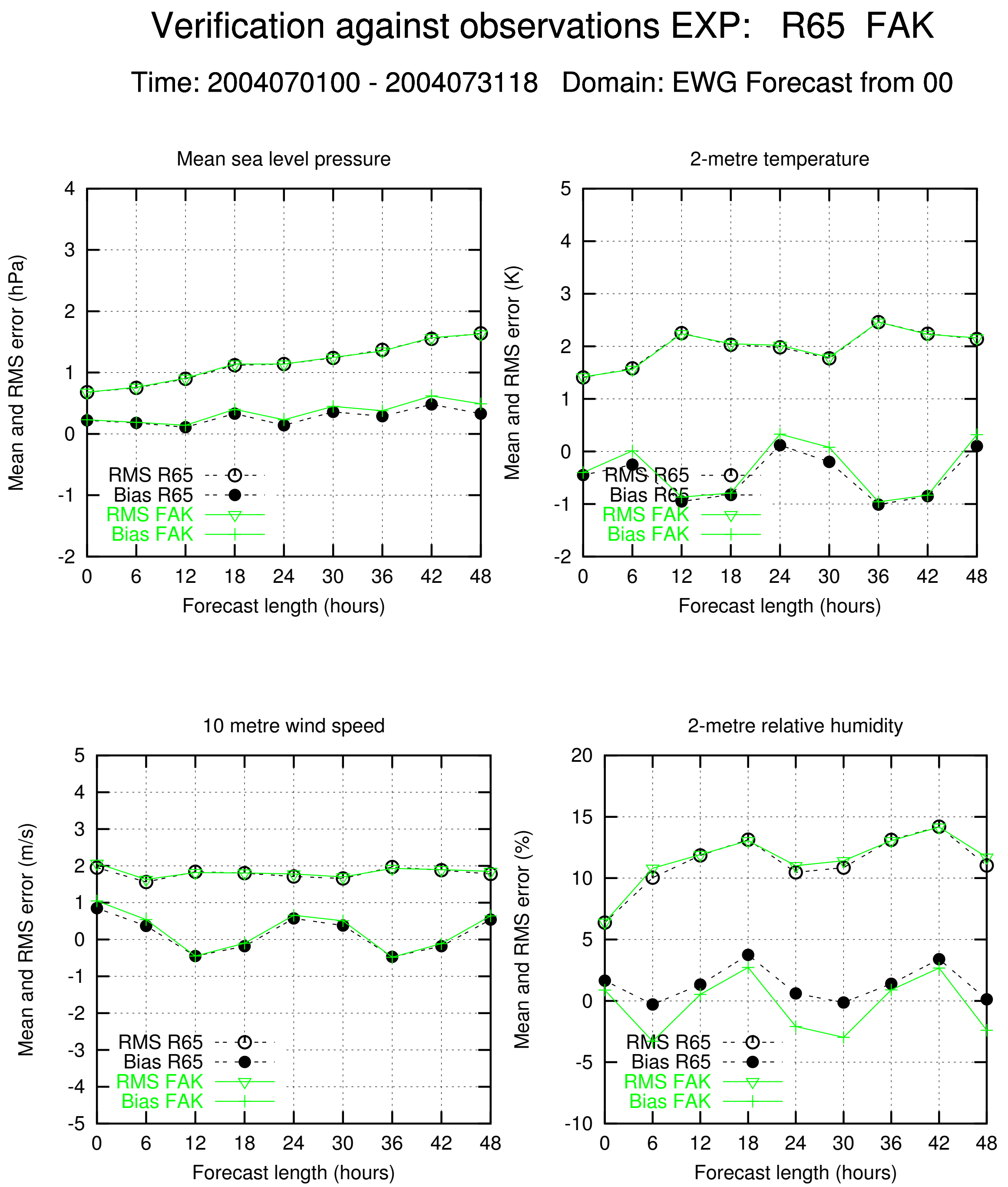


Figure 13: *Observation verification (EWGLAM stations) scores of surface pressure, 10-metre wind speed, 2-metre temperature and 2-metre relative humidity as a function of forecast length, for R65 and FAK runs in July 2004. Forecasts from 00 UTC analyses are included only.*

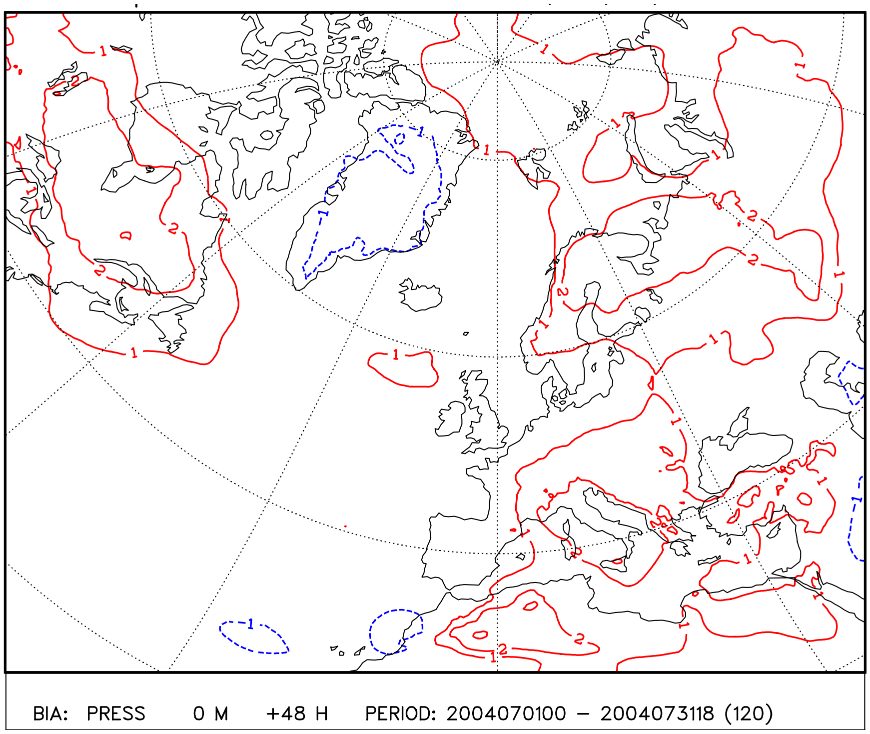


Figure 14: *$P_{msl}$ bias (forecast minus analysis) in 48 h RCR forecasts, for July 2004. Contour interval: 1 hPa. The zero isoline not plotted, negative values indicated with dashed lines.*

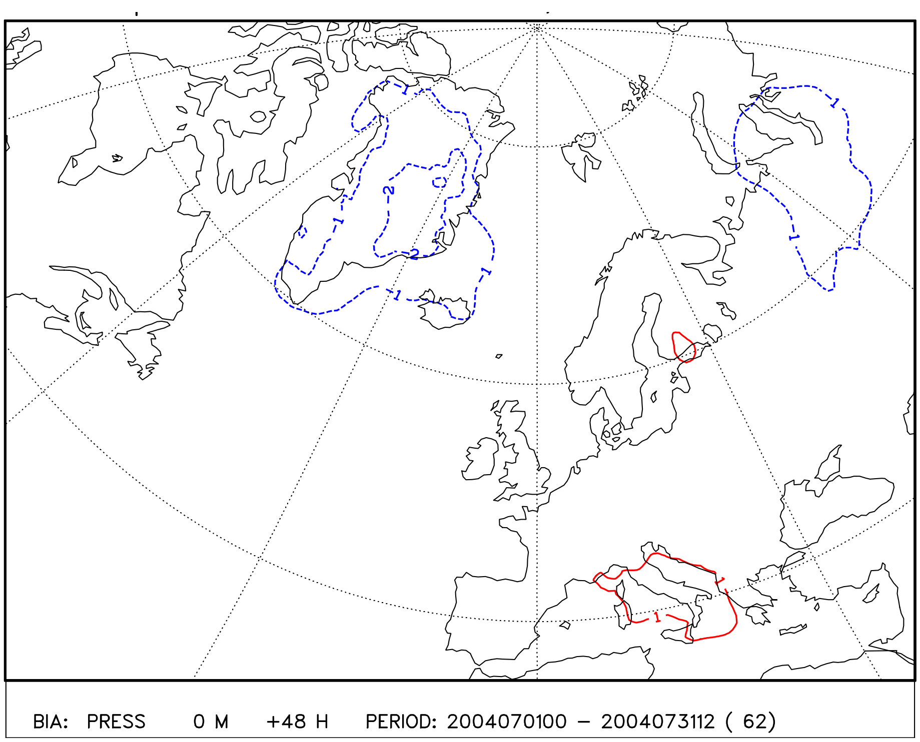


Figure 15: *$P_{msl}$ bias (forecast minus analysis) in 48 h R65 forecasts, for July 2004. Contour interval: 1 hPa. The zero isoline not plotted, negative values indicated with dashed lines.*

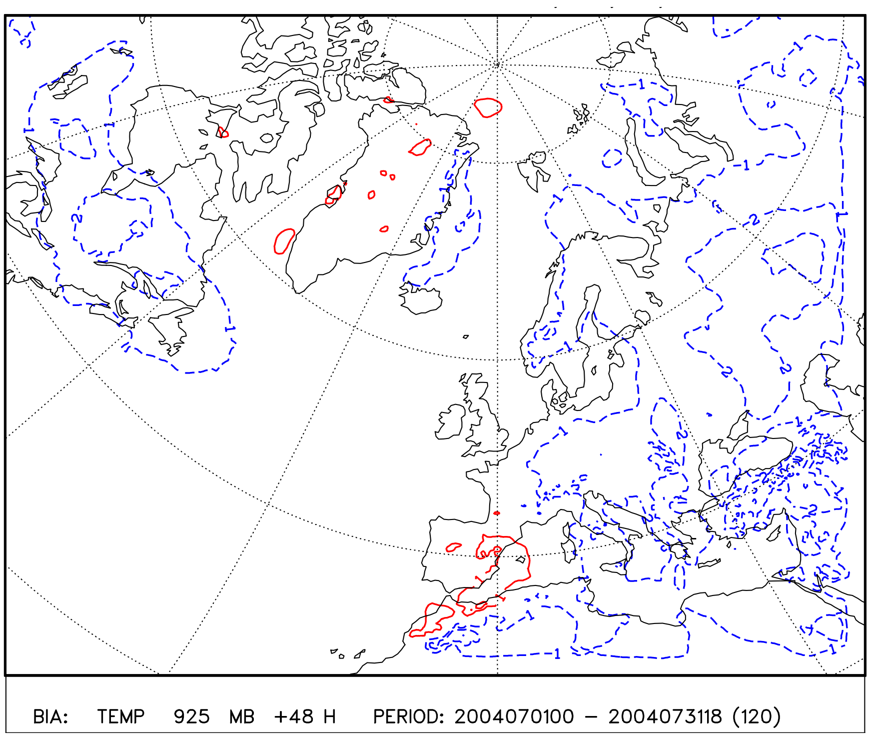


Figure 16: $T_{925}$ *bias (forecast minus analysis) in 48 h RCR forecasts, for July 2004. Contour interval: 1° C. The zero isoline not plotted, negative values indicated with dashed lines.*

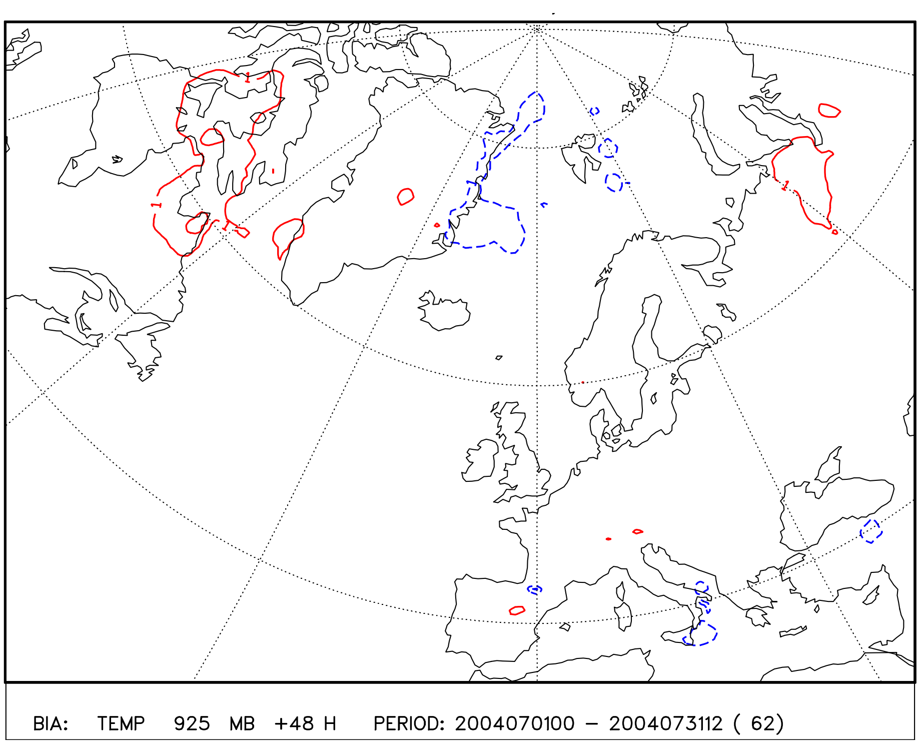


Figure 17: $T_{925}$ *bias (forecast minus analysis) in 48 h R65 forecasts, for July 2004. Contour interval: 1° C. The zero isoline not plotted, negative values indicated with dashed lines.*

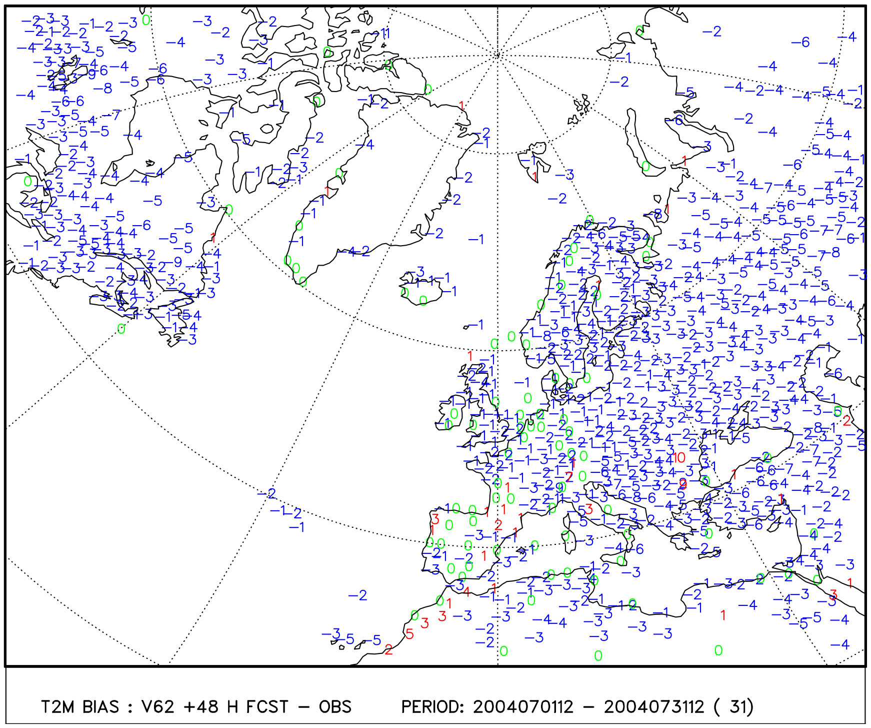


Figure 18: $T_{2m}$ *bias (calculated against observations) in 48 h RCR forecasts valid at 12 UTC, for July 2004.*

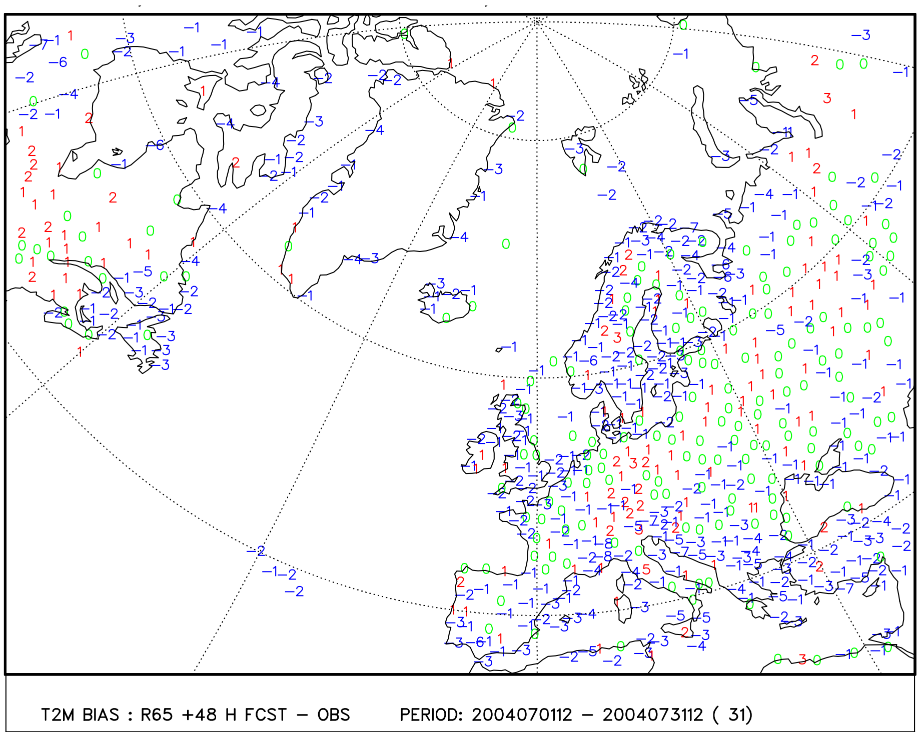


Figure 19: $T_{2m}$ *bias (calculated against observations) in 48 h R65 forecasts valid at 12 UTC, for July 2004.*

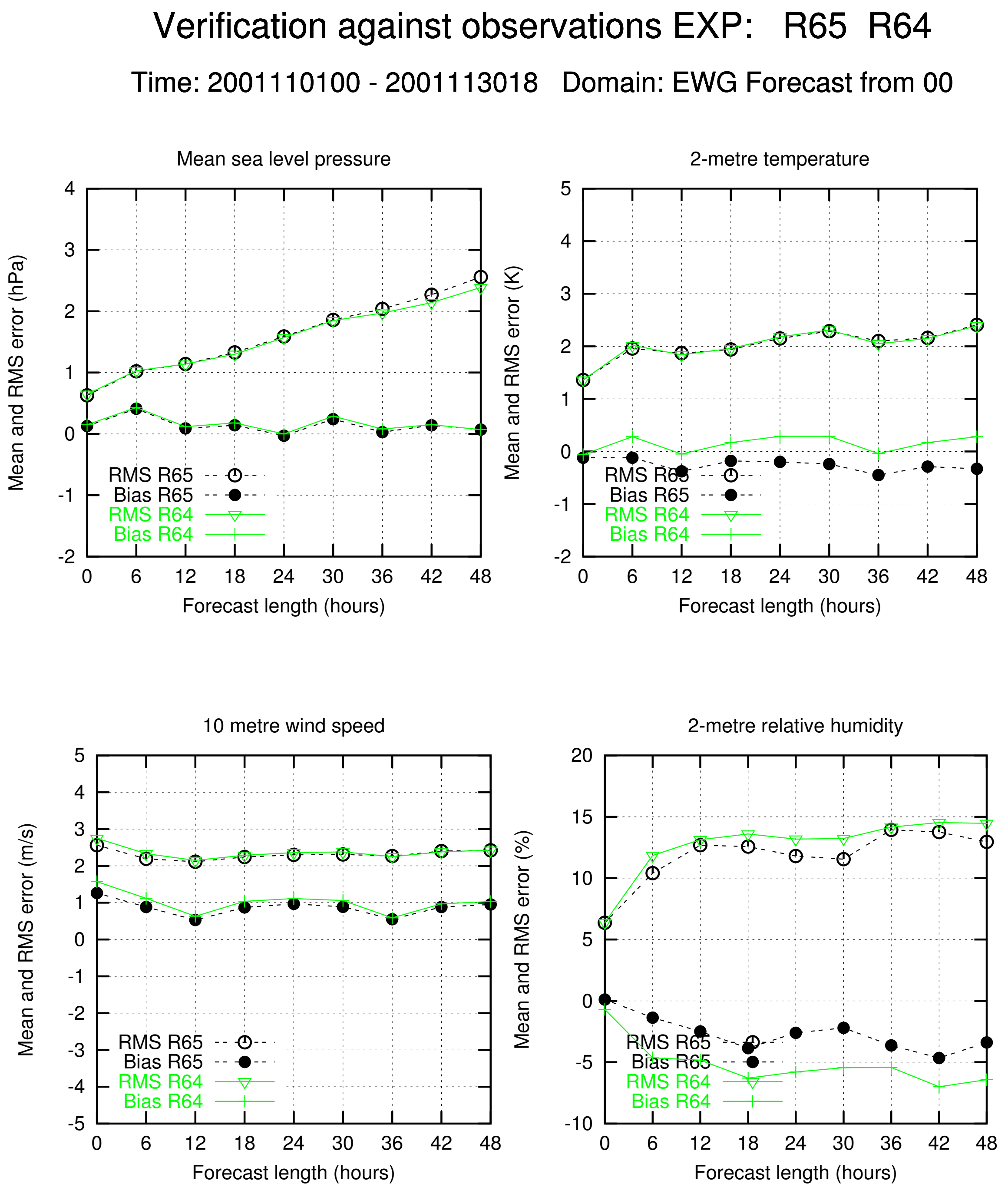


Figure 20: *Observation verification (EWGLAM stations) scores of surface pressure, 10-metre wind speed, 2-metre temperature and 2-metre relative humidity as a function of forecast length, for R65 and RCR runs in November 2001. Forecasts from 00 UTC analyses are included only.*

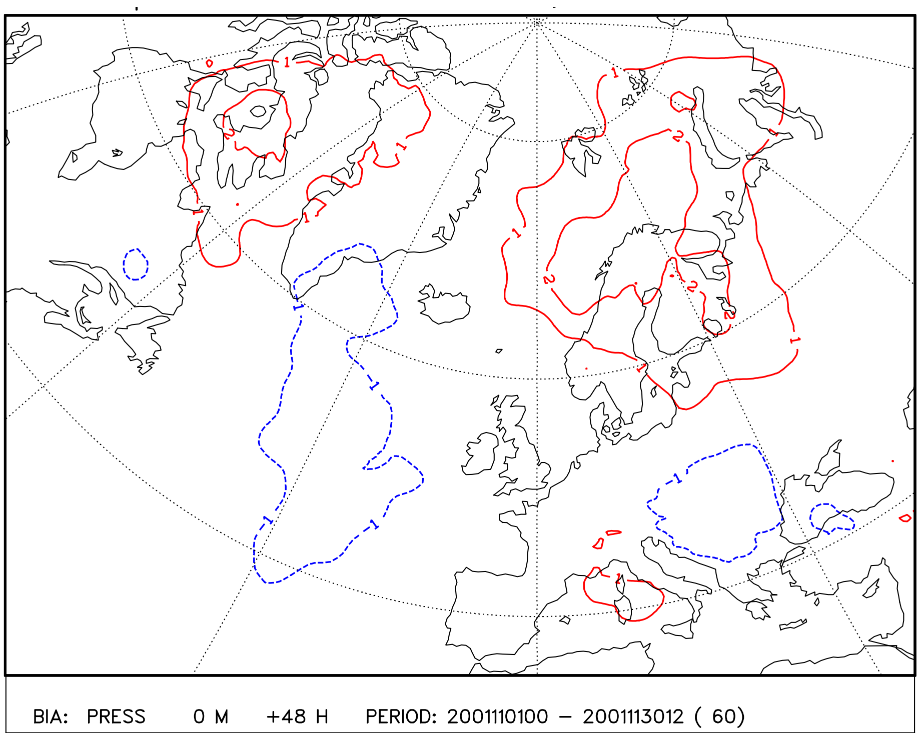


Figure 21: *$P_{msl}$ bias (forecast minus analysis) in 48 h R64 forecasts, for November 2001. Contour interval: 1 hPa. The zero isoline not plotted, negative values indicated with dashed lines.*

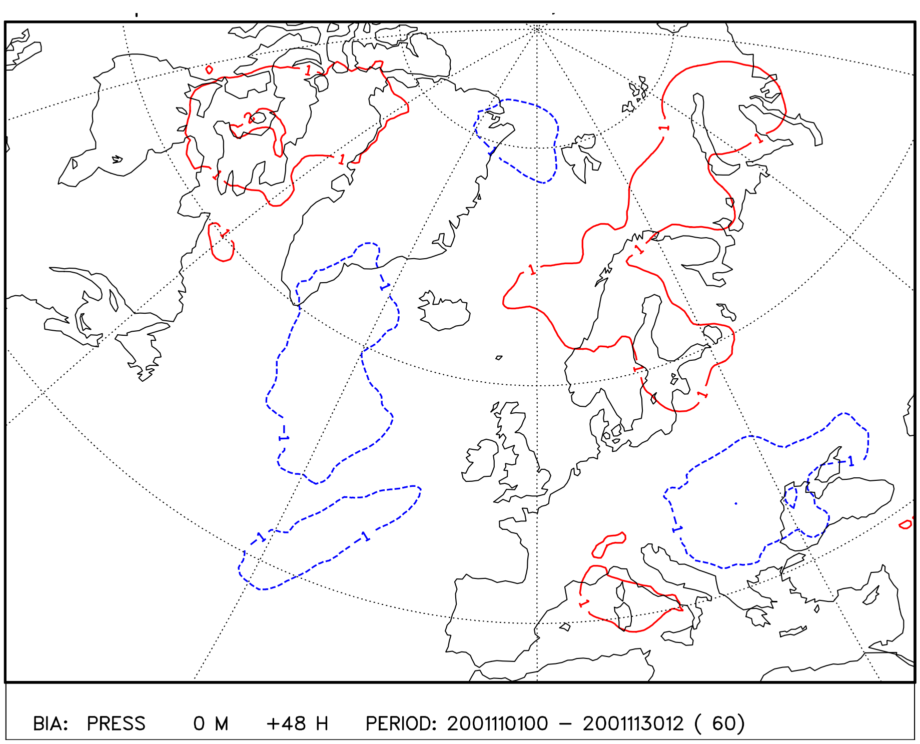


Figure 22: *$P_{msl}$ bias (forecast minus analysis) in 48 h R65 forecasts, for November 2001. Contour interval: 1 hPa. The zero isoline not plotted, negative values indicated with dashed lines.*

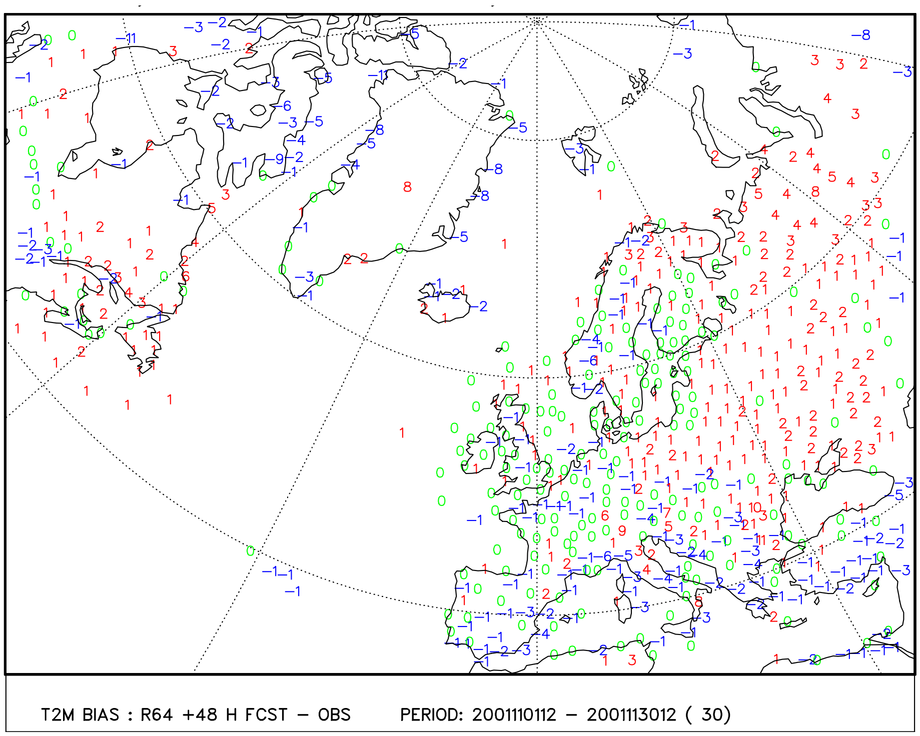


Figure 23: $T_{2m}$ *bias (calculated against observations) in 48 h R64 forecasts valid at 12 UTC, for November 2001.*

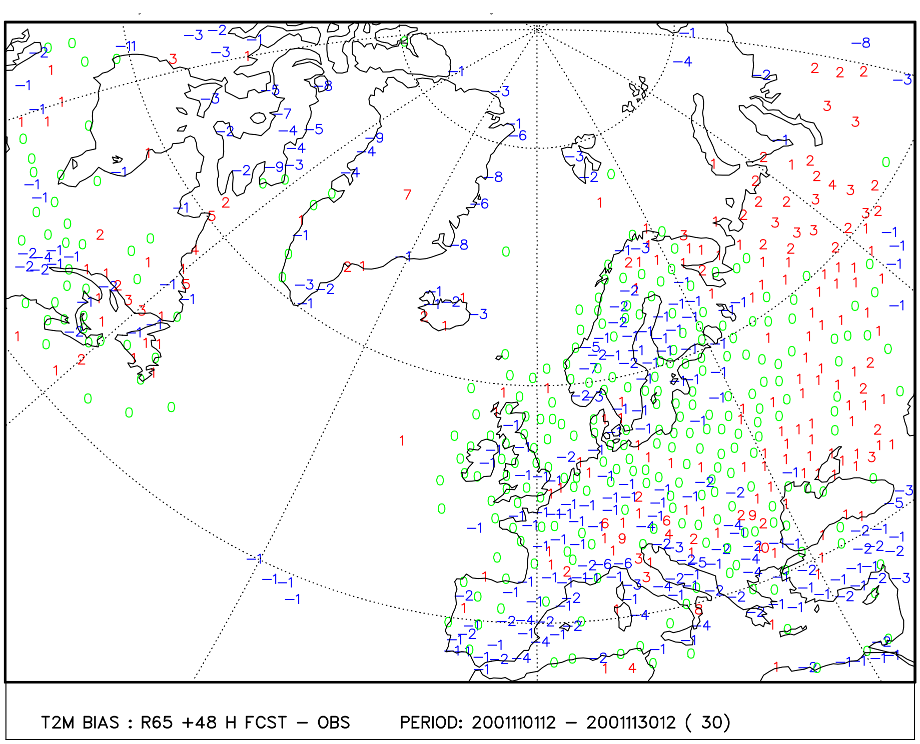


Figure 24: $T_{2m}$ *bias (calculated against observations) in 48 h R65 forecasts valid at 12 UTC, for November 2001.*